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Summary of Investigations 1984, Saskatchewan Geological Survey

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FOREWORD

With the upsurge in oil and gas drilling activity in the southern part of the province, the temporary 'hold' on uranium exploration and the developing interest in gold and precious metals, there has been a reformulation of priorities in the Saskatchewan Geological Survey. With the voluminous increase in well information from the southern part of the province, sedimentary geology activities have concentrated on rebuilding the data base. On the other hand, with the need to promote the gold and precious metal potential of the northern part of the province, the geoscientific field and field-related programs of the Survey have concentrated on 'gold belts' in the Precambrian Shield. The operational funds for this geoscience program are currently derived under the Canada-Saskatchewan Economic and Regional Development Agreement (ERDA), i.e. the Subsidiary Agreement on Mineral Development 1984, a 50:50 participation 5-year program. This year's Summary largely reports on projects under this agreement.

As in previous years we include reports from contracted agencies and other contributed reports bearing upon the geology of the province. Those interested in petroleum and natural gas will find contributions of some of the Survey's recent southern work in the volume 'Oil and Gas in Saskatchewan', a symposium held October 11-12, 1984 in Regina under the auspices of the Saskatchewan Geological Society.

J.E. Christopher
Director

October, 1984

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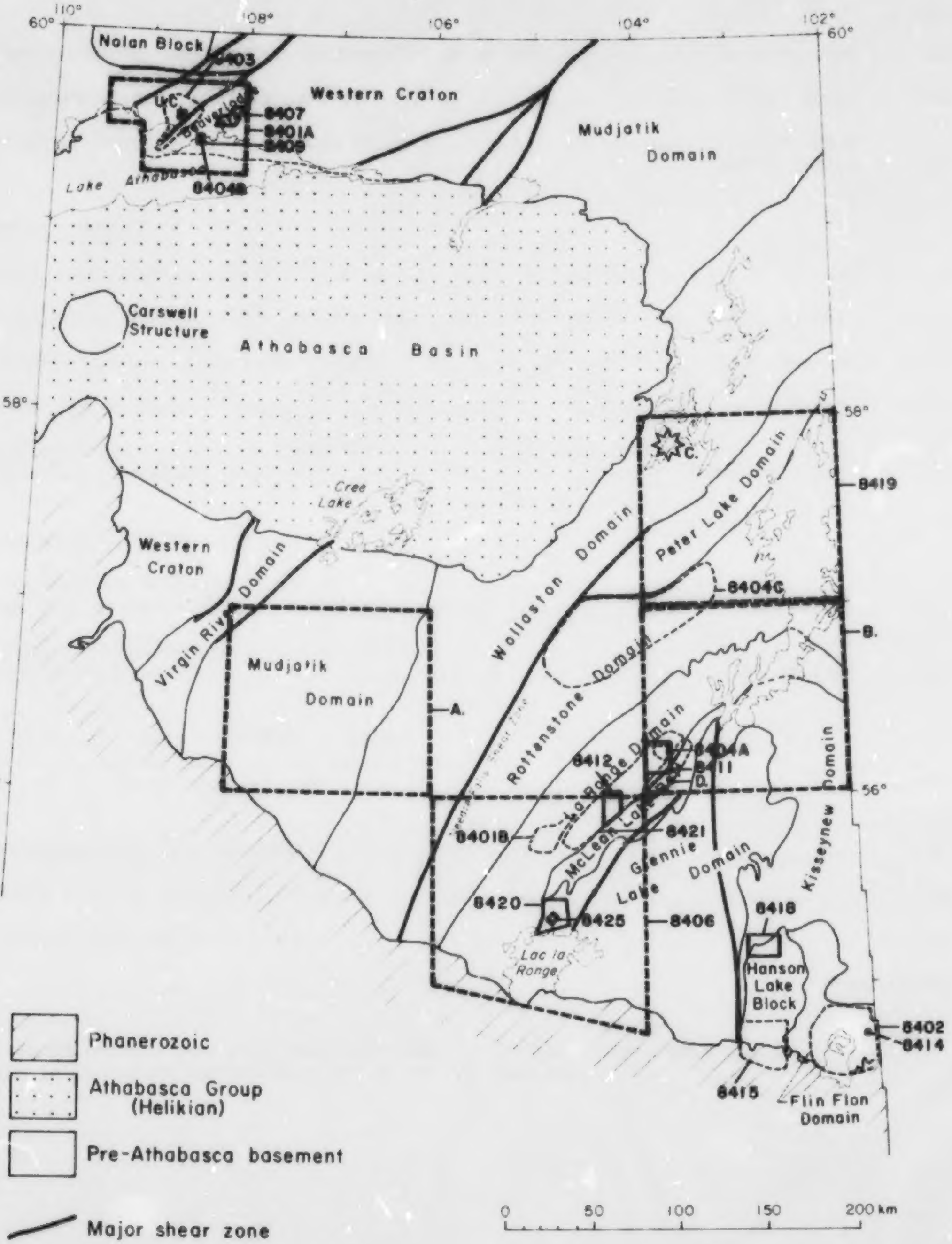
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Nolan Block
8403
Western Craton
8407
8401A
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Beaverlodge
U.C.
Lake Athabasca
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Carswell Structure
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Cree Lake
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Peter Lake Domain
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Kisseynew Domain
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8406
8418
Lac la Ronge
Hanson Lake Block
8402
8414
8415
Flin Flon Domain
Phanerozoic
Athabasca Group (Helikian)
Pre-Athabasca basement
Major shear zone
0
50
100
150
200 km

Figure 1 - Location of projects or reports in hand, 1984-85. Numbers or letters on map refer to project numbers or letters listed opposite.

Introduction

by R. Macdonald and T.I.I. Sibbald

This year's Summary of Investigations is concerned almost entirely with the 5-year ERDA Geoscience Program which commenced this summer in the northern part of the province. The federal geoscience component comprises mainly airborne geophysical and lake sediment geochemical surveys, as well as mineral deposit and thematic regional geological investigations. Activities to date are summarized here in a report by the GSC. In addition, the federal agencies will be involved in mineral technology and mineral development studies.

The province through the Geological Survey is currently concentrating mainly on geoscience investigations under the headings "Gold Belt Geology" and "Biogeochemical Method and Survey". The Gold Belt Geology program comprises most of the projects reported in this Summary of Investigations and is expected to provide the main thrust of the provincial component for the next four years. Current projects range from 1:20,000 scale mapping of terrain perceived to have a high gold potential, to detailed mineral deposit and geochemical studies.

Although numerous of gold occurrences have been known for many years in the La Ronge and Flin Flon areas, gold production from the Province has been small, and the Geological Survey has never previously conducted a program focussed primarily on this

Project Number	Area/ Short Title	Project Leader	Notes
Thematic Geological 1:20,000 Scale Mapping			
8411	Waddy Lake Area	C.T. Harper	1
8412	Star Lake Area	D.J. Thomas	1
Compilation Bedrock Geology			
8406	Lac la Ronge and Wapawekka Areas (NTS 73P/73I)	J.F. Lewry	1,3
A.	Mudjatik Area (NTS 74B)	M.W. Thomas and T.I.I. Sibbald	
B.	Reindeer Lake South Area (NTS 64D)	W.G.Q. Johnston and M.W. Thomas	7
8401A	Greater Beaverlodge Area	R. Macdonald with W.L. Slimmon	1
Review Geology and Other Studies			
8407	Review Geology, Stephens Lake Area	M.W. Thomas	1
8401B	Review Geology, Forbes Lake Area	R. Macdonald	1
8418	Geological Investigations, Pelican Narrows Area	L.O. Craig	1,4
8403	Martin Sedimentology	P.K. Mazimhaka and H.E. Hendry	1,3
C.	Plagioclasite in the Wollaston Belt	E.C. Appleyard	5
B.	McLennan Group Meta-arkoses, Jaysmith-Waddy Lakes Segment	M. Nighswander and J.F. Lewry	
Geochronological Investigations			
8408	Rb/Sr Geochronology	K. Bell and J. Blenkinsop	2.3
8404	U/Pb (zircon) Geochronology	M.E. Bickford and W.R. Van Schmus	1a,2,4
8404A	U/Pb (zircon) Studies, Nistoaraini-Waddy Lakes Area	C. Livesey	1a,4
8404B	U/Pb (zircon) Studies, Goldfields Area	S. Persons	1a,4
8404C	U/Pb (zircon) Studies, Wathaman Batholith	M. Meyer	1a,4
Geochemical Studies			
8421	Lithogeochemistry, Central La Ronge Belt	B.R. Watters	3
8415/ 8402	Lithogeochemistry, Flin Flon and Hanson Lake Areas	G.R. Parslow and J.W. Gaskarth	1a,3
Mineral Deposit Studies			
8409	Gold Metallogenesis, Goldfields Area	T.I.I. Sibbald	1
8425	Gold Metallogenesis, Sulphide Lake Area	T.I.I. Sibbald	1
8416	Gold in Saskatchewan (review)	Coombe Geoconsultants	3,7
8414	Gold Metallogenesis, Rio Deposit	J.G. Pearson	
8405	Mineralized Core Collection	A.J. Gracie	2
8419	Metallogenic Map Series	D.G. MacDougall	
	Gold Metallogenesis, and Waddy Lake	M. Mellinger	2,5
8420	Biogeochemical Method and Surveys, Sulphide Lake Area	C.E. Dunn	1
8420	Gold Lithogeochemistry, Sulphide Lake Area	B.P. Scott	1
8409	Biogeochemical Investigations, Goldfields Area	T.I.I. Sibbald and G. Buller	1

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[1] Field projects in 1984 (1a, part field project)

[2] Projects covering more than one location in 1984 not shown on map

[3] Contracted project 1984-85

[4] Project partially supported by Saskatchewan Energy and Mines in 1984-85

[5] Contributed report from other institution

[6] Not reported at present

[7] Final reporting this year

commodity. One of the first tasks has been to gather together all existing information on gold occurrences in the province in the context of the regional geology. This compilation, prepared by Coombe Geoconsultants Ltd. of Regina, is expected to appear concurrently with this Summary as a report entitled "Gold in Saskatchewan".

The Biogeochemical Method and Surveys program is an expansion of investigations initiated previously by the Geological Survey. The biogeochemical method is being developed and applied to exploration in the gold belts. This year a major part of the Sulphide Lake sheet area was systematically covered by biogeochemical surveys backed up with lithogeochemical studies (Project 8420, C.E. Dunn and B.P. Scott). A smaller biogeochemical investigation was also carried out in the Box Mine - Athona peninsula area near Beaverlodge Lake using similar methods (Project 8409, T.I.I. Sibbald and G. Buller).

In addition to covering the ERDA program, this volume also contains reports by the Resident Geologists on current exploration activities in northern Saskatchewan, as well as a number of progress reports on current research relevant to Saskatchewan provided by university researchers and the Saskatchewan Research Council. The location of projects in hand is given in Fig. 1.

Bedrock mapping at a scale of 1:20,000 was commenced this year in the Central La Ronge Metavolcanic Belt (Projects 8411 and 8412, C.T. Harper, D.J. Thomas). A project was also initiated in the Sulphide Lake gold camp at the south end of the belt (Project 8425, T.I.I. Sibbald). Mapping at this scale is expected to be accelerated for completion in two or three years, providing a much better basis for geological and metallogenic modelling in what is currently regarded as the most promising gold exploration terrain in the province. This work is being supplemented by lithogeochemical studies, at the Universtiy of Regina, of samples collected during the mapping (Project 8421, B. Watters).

Lithogeochemical projects in the Flin Flon - Amisk Lake and Hanson Lake areas, which have been in progress for several years at the Universities of Regina and Aston (Projects 8402 and 8415, G.R. Parslow, J.W. Gaskarth), will be reported on this year. An abstract of these imminent reports is included here. The authors have processed a very large number of samples and postulate among conclusions of exploration interest the existence of oceanic rift 'black smoker' terrain.

Gold metallogenic investigations in the Flin Flon - Amisk Lake area (Project 8414, J.G. Pearson), undertaken by the resident geologist at Creighton since 1979, have included exmination of most gold prospects in this region. A report on this work is currently in preparation.

Detailed mapping around the Rio zone gold deposit of Flin Flon Mines Ltd. this summer indicated possible structural controls of mineralization.

Compilation bedrock geology maps at 1:250,000 scale have been produced for the Mudjatik area (NTS 74B, M.W. Thomas, T.I.I. Sibbald) and La Ronge - Wapawekka areas (NTS 73P/73I; Project 8406, J.F. Lewry). Fieldwork this summer in the latter area has indicated a number of revisions to ideas on rock precursors, particularly in the Glennie Domain, where large areas formerly mapped as supracrustal are now interpreted as sheared plutonic rocks. Metasedimentary rocks around Forbes Lake, immediately west of the Central La Ronge Metavolcanic Belt, have been largely reinterpreted as volcanic or volcaniclastic in origin (Project 8401B, R. Macdonald). A final version of the Reindeer Lake South (NTS 64D) sheet area has recently been published (W.G.Q. Johnston and M.W. Thomas).

"Project Beaverlodge" studies, now included with the Gold Belt Geology program, are being largely wound up this year. A preliminary bedrock compilation map of the Beaverlodge area is presented here at 1:100,000 scale (Project 8401A, R. Macdonald and W.L. Slimmon). A better understanding of the quartzofeldspathic gneisses east of Beaverlodge is emerging and the pluton centred around Stephens Lake has 'grown' considerably this summer (Project 8407, M.W. Thomas). Detailed mapping in the gold-bearing Goldfields Peninsula (Project 8409, T.I.I. Sibbald) has confirmed a complex history of granite intrusion and granitization. The University of Saskatchewan is now deeply involved in a study of the Martin Group (Project 8403, P.K. Mazimhaka and H.E. Hendry).

Essential to developing the geological framework and ideas on the tectonic evolution of the province, is the geochronological program. More Rb/Sr results are presented from the Carleton University laboratory (Project 8408, K. Bell and J. Blenkinsop). A major program of U/Pb zircon determinations is now in full swing through the University of Kansas (Project 8404, M.E. Bickford and W.R. Van Schmus) who are funding the analytical work and engaging three M.Sc. students in selected areas; counterpart ERDA funds are providing logistical support in the field.

A new project was initiated in 1983 to generate a 1:250,000 scale metallogenic map series (Project 8419, D.G. MacDougall). These maps provide details of location, metal association, development status and type of mineralization, as well as references to information on mineral occurrences. The series uses the compilation bedrock geology maps as a base, and marginal notations are provided to develop metallogenic concepts. The first of the new series (NTS 64E, Reindeer Lake North) has recently been released.

The mineralized core collection and Saskatchewan Mineral Deposits Index are Mineral Industry support services provided under the ERDA program. The Mineralized Core Collection (Project 8405, A.J. Gracie) is primarily maintained by the resident geologist at the Precambrian Geological Laboratory in La Ronge. A small storage facility is also maintained by the resident geologist in Creighton. Additions to the collection this year include material from the Deilmann orebody at Key Lake, from several gold prospects in the La Ronge belt and from base metal and gold properties in the Flin Flon area. The cooperation of companies who submitted core is gratefully acknowledged. A new index for the La Ronge collection was prepared during the year and will shortly be available on open file.

The Saskatchewan Mineral Deposits Index, a manual and computer listing of mineral occurrences in northern Saskatchewan, is being prepared for open file release (V. Harris).

The development of the Precambrian geological files and indexes (Precambrian Original Data, Precambrian Resource File, Precambrian Sample Index and Geochemical File) continues (N. Lee). A directory of these files is expected to be available in November 1984.

THEMATIC GEOLOGICAL MAPPING

Project 8411

Geological Mapping, Waddy Lake Area (part of NTS 64D-4 and -5)

by C.T. Harper

Harper, C.T. (1984): Geological mapping, Waddy Lake area (part of NTS 64D-4 and -5); *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The geology of a 250 km^2 area centred about 150 km northeast of La Ronge (Fig. 1) has been mapped at a scale of 1:20,000. Access is attained by float-equipped aircraft and via a bush road, which leaves highway 102 near the settlement of Brabant Lake and terminates 16 km to the northwest at the Komis gold deposit of Waddy Lake Resources Ltd.

The area is characterized by generally undulating terrain, with local relief rarely exceeding 30 m. Bedrock is relatively abundant but commonly masked by lichen and moss. Bedrock exposure is generally better east and south of Waddy Lake where forest fires swept the area some fifteen to twenty years ago.

The mapped area is included in the 1:63,360 scale mapping of Byers (1948) and Johnston (1969, 1970) and the 1:31,680 scale mapping of Kirkland (1959); it includes a 45 km^2 area mapped in detail by Harper (1974, 1976, 1983). Coombe (1976) and Johnston (1981) carried out geological investigations in the vicinity of the Komis deposit.

The Waddy Lake area lies within the La Ronge Domain, which is dominated by a central zone of volcanics and volcaniclastics flanked by marginal arkosic sediments and more distal basinal greywackes, all of which are intruded by granitic to gabbroic plutons. The volcanic rocks are dominantly calc-alkaline but have a tholeiitic to calc-alkaline trend and are typical of island arc volcanism (Harper, 1976, 1983; Watters, 1981). They range from ultramafic (komatiitic) flows at the base through basaltic and andesitic flows and pyroclastics, to dacitic and rhyolitic flows and pyroclastics. Several cycles of mafic to felsic volcanism are developed locally. Sedimentary rocks underlie and are interlayered with the volcanic rocks.

In the Waddy Lake area the upper greenschist to amphibolite facies grade volcano-sedimentary complex reaches a maximum width of about 20 km and is effectively bounded by five major plutons: the Nistoassini Lakes, Kenwood Lake, Brindson Lake, Payn Creek and Contact Lake Plutons and the smaller Boundary Lake pluton. Numerous smaller intrusive bodies occur throughout the area. Primary volcanic and sedimentary structures abound but structural complexities make it difficult to determine a coherent stratigraphy across the entire area. Therefore to simplify this summary, the volcano-sedimentary rocks will be described under the broader headings of ultramafic, mafic, intermediate and felsic volcanics, and lower and intravolcanic sedimentary rocks. All the volcanic rocks have been metamorphosed, but to avoid repetition the term "meta" is deleted from the following descriptions. The character of the volcanic rocks, such as flows, pillow lavas, pillow breccias, agglomerate and tuffs, is indicated by one or more suffixes on the accompanying maps.

Lower Sedimentary Rocks (Unit S)

Sedimentary rocks occur in four widely separated areas referred to as the Kenwood, Contact Lake, Lower Waddy Lake and Payn Creek sections. Preserved primary sedimentary structures, such as channel scours, graded bedding and slump structures (see Plate 14, Harper, 1983), suggest that these sediments underlie the volcanic succession; however, their contact has not been observed. Each section is dominated by an interlayered sequence of arkose, impure arkose, argillite and greywacke. Arkosic and polymict conglomerate are abundant in the Kenwood section and are reported in the Lower Waddy Lake section (Byers, 1948; Fox and Johnston, 1981).

Arkoses (subunit Sa) are pink, pinkish-grey and grey on both fresh and weathered surfaces, fine grained (<1 mm), finely laminated to thinly bedded (up to 8 cm thick) and locally show graded bedding, with repeated upward fining cycles and faint suggestions of cross-bedding. Slump structures are preserved at several places in the Contact Lake section. A coarser, granular (1 to 3 mm) arkose is common in the Kenwood section.

Argillites (subunit Sb) weather light to dark grey, commonly have splotchy iron staining, are aphanitic to very fine grained and finely laminated. Millimetre-sized garnets are common at higher metamorphic grade.

Immediately adjacent to the Contact Lake Pluton a high-grade equivalent is represented by a sillimanite-garnet-biotite gneiss.

Greywacke (subunit Sg) is light to dark grey to greenish grey, fine grained (<1 mm) and thinly bedded (generally less than 10 cm thick). The greywackes vary from siliceous to mafic in composition which suggests different source material. Some of the greywackes appear tuffaceous, suggesting contemporaneous volcanism. In the Kenwood section 20 to 30 cm thick beds of white, fine- to medium-grained (1 to 2 mm) quartzite are interbedded with the greywacke.

Arkosic and polymict conglomerate (subunit Sc) occur at several stratigraphic levels in the Kenwood section. They are pink to grey, dominantly matrix (arkosic) supported and contain round to subangular elongate pebbles and cobbles (0.5 to 30 cm long) of the associated sediments with fewer clasts of dacitic to andesitic volcanics and granite (see Plate 13, Harper, 1983). Individual beds range from 15 cm to at least 5 m in thickness, but conglomeratic sections attain thicknesses of up to 250 m. The conglomerate in the Lower Waddy Lake section occurs in a 30 to 40 m thick band along the sediment-volcanic contact. It is described by Byers (1948) as consisting of subangular to rounded clasts, 0.6 to 10 cm in size, of hornblende-biotite granite, greywacke, chert, argillite, amphibolite and volcanics in a fine-grained quartz-biotite matrix.

In addition to arkose and argillite, the sediments cropping out along the Payn Creek Pluton comprise fine- to medium-grained (<2 mm), dark grey, well-foliated, hornblende-biotite quartzofeldspathic gneiss, which is probably a higher metamorphic grade equivalent of greywacke. Concordant layers of white coarse-grained granite common in these outcrops appear to be derived from the Payn Creek Pluton rather than by anatexis of the country rock.

Ultramafic Volcanics (Unit U)

Byers (1948) outlined a group of variously serpentinized pyroxenites and peridotites at the south end of Lower Waddy Lake, which he considered to be wholly of intrusive origin. Fox and Johnston (1981), who remapped these rocks, considered them to be extrusive, based on petrographic and geochemical studies, their stratiform aspect and the presence of amygdules, thin stacked flows(?) and pillow-like structures. In addition to the pyroxenitic and peridotitic varieties, Fox and Johnston also included an assemblage of very distinctive bright green weathering rocks, which Byers (1948) included in his mafic volcanic unit. This assemblage has a komatiitic fractionation trend, but as they have unusually low Ti and Zr contents Fox and Johnston preferred to classify them as peridotitic, pyroxenitic and basaltic boninites.

The present mapping confirms the extrusive nature of the ultramafic rocks, some of which contain amygdules and pillows along with thin stacked flows. Small-scale layering (5 to 10 cm thick) of apparently monomineralic composition may represent smaller cumulate intrusive bodies. Three subunits of the magnesian volcanics are distinguished on the accompanying map (Waddy Lake Area, Sheet 2); these are peridotitic-pyroxenitic rocks, green basalt and black-weathering basalt.

The peridotitic-pyroxenitic rocks (subunit Up) are highly variable in colour, grain size and degree of serpentinization. They range from white, light grey, bluish-grey, pink, pinkish-, reddish-, yellowish- and greenish-brown, brown to black to green weathering. Some of the colouration is due to the degree of oxidation of magnetite, which can be very abundant in places. Fresh surfaces are commonly dark grey or green. The rocks vary from fine to coarse grained, are commonly well foliated and appear to be composed mainly of tremolite, talc, chlorite, calcite and minor plagioclase. Negligible to almost complete serpentinization of some rocks has occurred, with the strongly serpentinized rocks also cut by 1 to 10 mm thick anastomosing serpentine veinlets, which weather white but are green to bluish-green on fresh broken surfaces.

Pseudomorphed pyroxene phenocrysts are preserved locally and relict olivine and pyroxene are reported (Byers, 1948). Magnetite occurs as disseminations and as anastomosing veinlets in the more strongly altered rocks and accounts for the magnetic high across the south end of Waddy Lake (Geological Survey of Canada, 1964).

The green basalts (subunit Ugb) are characterized by a distinctive grass green weathering and a bright emerald green colour on fresh surfaces. A network of white quartz and plagioclase veins and/or layers in places comprise up to 30 percent of the rock. These rocks are generally fine grained (<1 mm), well foliated and comprise chlorite, tremolite and actinolite with minor plagioclase and calcite. Most primary textures and structures have been obliterated by deformation and metamorphic recrystallization, producing a rather massive rock. Thin stacked flows and pillow-like structures are, however, preserved in places.

The black basalts (subunit Ubb) are black or greenish-black on both fresh and weathered surfaces, fine to medium grained, and comprise 60 to 90 percent hornblende accompanied by plagioclase. These rocks consist of massive flows, flows with pillows and pillow breccia, and more finely layered tuffaceous rocks.

Mafic Volcanics (Unit B)

The mafic volcanics unit includes all other basaltic rocks in the area. These consist of massive and amygdaloidal flows, pillow lavas, pillow breccias, flowtop breccia and tuffaceous rocks, as well as local interflow sediments and tuffs and flows of andesitic to rhyolitic composition. The basalts of this unit are typically pale to dark green, greenish-grey and greenish-black on weathered and fresh surfaces, aphanitic to fine grained and weakly to well foliated. They consist predominantly of chlorite, biotite, pale green amphiboles (actinolite-hornblende) and minor plagioclase. Quartz and calcite occur as amygdules. Biotite commonly occurs as 2 to 5 mm porphyroblasts which comprise up to 10 percent of the rock and preferentially weather out, producing a pitted surface. At higher metamorphic grade dark green to black hornblende is more abundant and dominant. Where calcite amygdules are leached the flows and pillows appear vesicular; the vesicle shape rarely shows much deformation. Amygdules range in diameter from less than a millimetre to 4 cm and in places have tube-like shapes up to 20 or 30 cm long suggestive of tube vesicles.

Pillow lavas and pillow breccias (hyaloclastites?) form mappable zones up to 300 m thick and traceable for 4 to 5 km. Three prominent zones are: 1) across the south end of Lower Nistoassini Lake, 2) across the north end of Upper Waddy Lake and 3) between Weedy and Contact Lakes. Throughout the area pillows are generally small (less than 0.5 m long), have narrow chilled margins, vesicular/amygdaloidal cores, and vary from weakly deformed to strongly flattened. Pillow breccia zones also contain abundant carbonate, as interpillow selvages, amygdules and cementing the fragmented pillow material (Plate 1A). Outcrops of the latter exposed at lake level are deeply eroded.

Intermediate Volcanics (Unit A)

The intermediate volcanics were identified in the field as andesite but probably include rocks ranging from basaltic to dacitic. They are probably the most abundant volcanic type in the area mapped, consisting of massive, porphyritic and amygdaloidal flows, flow breccias, pillow lavas and various pyroclastics from fine ash tuff to agglomerate. The andesites typically weather dark greenish-grey to greenish-black, are dark green on fresh surface, aphanitic to very fine grained, finely foliated and are massive to very delicately laminated. Porphyritic flows and/or crystal tuffs contain 1 to 10 mm long plagioclase phenocrysts which generally comprise less than 20 percent of the rock. The andesites are typically composed of 40 to 60 percent hornblende ± biotite ± chlorite along with plagioclase. Disseminated pyrite and magnetite are present locally. Amygdules, where present, are generally less than 10 mm in diameter and composed of quartz, feldspar and/or calcite.

Flow or autobreccias, common south and southwest of Round Lake and in the area north of Contact and Weedy Lakes, consist of subangular to rounded fragments (from several millimetres to 20 cm across) of earlier formed flow material enveloped in later flow material of similar composition. The fragments and matrix are easily seen on weathered surfaces.

The pyroclastic varieties show a full range from finely laminated ash tuffs, through crystal and/or lithic lapilli tuffs to thickly layered agglomerates. Fragments in the agglomerates range up to 30 cm in length, are intensely flattened and more heterolithic, and include dacitic to rhyolitic material.

Felsic Volcanics (Units D and R)

Included in this category are rocks mapped in the field as dacites (unit D) and rhyodacites to rhyolites (unit R), of which the dacites were previously included in Byers' (1948) unit 2. Felsic volcanic rocks are more common than Byers indicated. A number of felsic volcanic centres or domes have been defined, which may prove to be of economic significance. Taken as a group felsic volcanics attain thicknesses of up to 700 m in several places.

Dacitic volcanics (unit D) are light to dark grey and brownish-grey on both fresh and weathered surfaces, aphanitic to very fine grained and finely foliated. Phenocrysts of plagioclase and quartz, metamorphic biotite and hornblende, and disseminated magnetite are recognised, the last mentioned being rather common south and east of Oven Lake. The dacites range from finely laminated ash tuffs to more thickly layered crystal and/or lithic lapilli tuffs, tuff breccias and agglomerates. Massive amygdaloidal, porphyritic and pillowed flows, flow breccias and possible lahars also occur. This diversity suggests a range from submarine to subaerial volcanism.

Plagioclase phenocrysts 1 to 4 mm long occur in both flows and tuffs. Some flows contain up to 10 percent needle-like hornblende crystals commonly less than 5 mm long. Quartz phenocrysts are rare. Lithic tuffs and agglomerates commonly contain fragments that are compositionally similar to the matrix, such as the porphyritic flows, but also contain exotic fragments such as andesite and rhyolite.

Excellently preserved dacitic pillow lavas occur immediately west of Pillow Lake and southwest of Round Lake. At Round Lake individual pillowed flows can be traced across the outcrop (Plate 1B). The lava flowed from north to south and several flows terminated in flow-toe or pillow breccia. Flow-toe breccias are also excellently

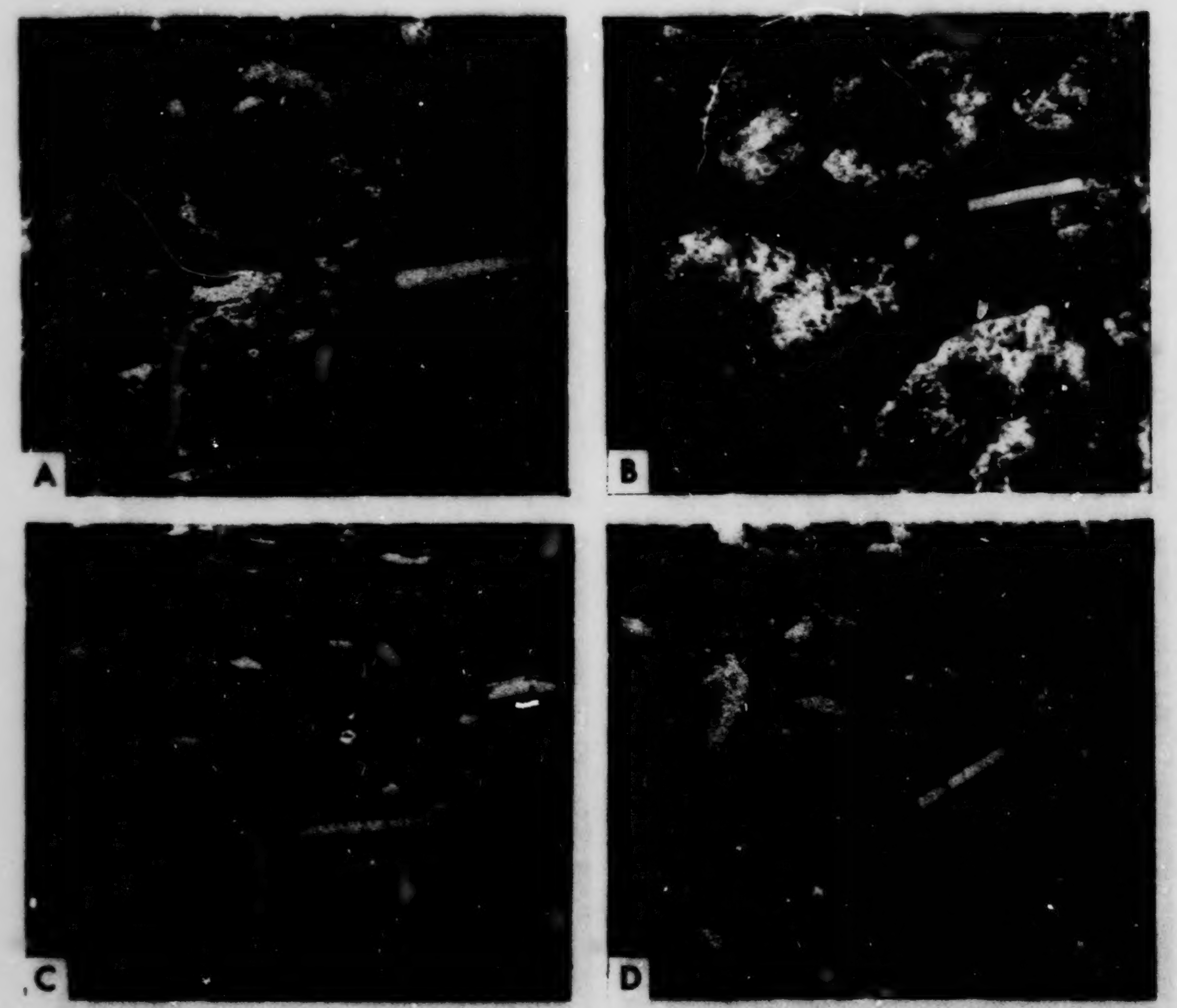

Plate 1 - A) Basaltic pillow breccia at north end of Upper Waddy Lake with calcite in amygdules in scattered isolated pillows (top centre), as the matrix (light grey) to brecciated pillow debris (dark grey); flow top is to the top of photo; scale is 15 cm; B) Dacitic pillow lavas showing necking (arrows) between subsequently formed pillows; scale is 15 cm; C) Dacitic volcanic debris flow/lahar at Kidney Lake containing angular to rounded fragments; note the heterolithic nature of the fragments; scale is 15 cm; D) Rhyolitic agglomerate near Kidney Lake, showing insignificant deformation of highly angular fragments; scale is 15 cm.

exposed on a large sluiced outcrop at the southeast corner of Wedge Lake.

Around Kidney Lake rhyolitic and dacitic agglomerates are interlayered with andesitic tuffs, feldspar porphyritic dacitic flows and a very heterolithic debris flow breccia or lahar. The breccia contains angular to rounded, poorly sorted fragments, ranging from a few millimetres to over a metre in length, of all the surrounding rock types in a hornblende-biotite-plagioclase matrix (Plate 1C).

Synvolcanic dacitic feldspar (±quartz) porphyry dykes from a few tens of centimetres to 5 m thick, are similar in appearance to the flows but are generally coarser grained (2 to 5 mm for phenocrysts and <1 mm for the matrix) and have intrusive contacts. Phenocrysts comprise up to 40 percent of the rock.

Rhyolites and rhyodacites (unit R and subunit Rd) are typically white, pink, and light grey on fresh and weathered surfaces, aphanitic, finely foliated, and fracture conchoidally. They include massive flows, tuffs and agglomerates and sulphide-bearing explosion breccias. Quartz eye and/or feldspar porphyries occur in a number of places and appear to be mainly tuffs and flows rather than intrusive rocks.

Around the mouth of the Kenwood River the upper 100 to 200 m of the felsic volcanic succession consists largely of dacitic to rhyodacitic tuffs and rhyolite flows up to 5 m thick (see Plate 7, Harper, 1983). The top is capped in places by sulphide-bearing explosion breccias, rhyolite agglomerate and minor conglomerate (see Plates 8 and 9, Harper, 1983). In addition to rhyolite fragments, the agglomerate also contains a few granitic and mafic volcanic fragments, and is also sulphide bearing. The conglomerate contains rounded clasts of sugary quartzite, arkose, and felsic volcanics, and is associated with some fine-grained clastic sediment. This package of rocks bears some resemblance to rocks found in hydrothermal explosion craters in Yellowstone National Park (Muffler et al., 1971).

Extending west from the Pillow Lake felsic dome is a major wedge of agglomerate up to 400 m thick. Thinner agglomerate horizons occur east of Pillow Lake. The base of the unit consists of large rhyolite fragments up to 1 m long and 30 cm thick encased in a chloritic-biotitic matrix. Fragments decrease in size upwards and westwards with a corresponding increase in the proportion of matrix and mafic fragments. The alternation of white to light grey felsic fragments with the dark green matrix and mafic fragments has produced a striped rock (see Plate 11, Harper, 1983). A few granitic fragments are also present. The Churchill Minerals copper showing lies in this wedge associated with quartz-sericite-pyrite schist, sulphide-facies iron formation and a small diorite sill. Other rhyolitic agglomerates associated with sulphide mineralization occur east of the north end of Upper Waddy Lake.

Rhyolitic agglomerates and thin flows also occur around Kidney Lake. The fragments in these horizons range from essentially undeformed angular blocks to extremely elongate lensoid fragments up to 1 m (Plate 1D and 2A). The abundance of coarse pyroclastics in this area suggests the proximity of a volcanic vent.

Several bodies of a distinctive blue quartz-eye rhyolite are located around the periphery of a granitic stock underlying Round Lake. The quartz eyes are a pale to medium blue, range from 1 to 4 mm diameter, and comprise 5 to 20 percent of the rock. Feldspar phenocrysts (1 to 2 mm across) comprise less than 10 percent of the rock. Other rhyolites in the area contain smaller clear quartz phenocrysts or no quartz eyes at all. The rhyolite dome southwest of Lower Nistoassini Lake consists almost entirely of quartz-eye ± feldspar porphyritic rhyolite. The quartz eyes here are 1 to 4 mm in diameter, comprise 5 to 20 percent of the rock and are clear.

Some rhyodacite and rhyolite rocks south and southeast of Oven Lake contain up to 10 percent magnetite, accounting for the magnetic high in that region (Geological Survey of Canada, 1964). The magnetite occurs as 1 to 2 mm sized disseminations and in millimetre-sized veinlets.

Intravolcanic Sediments (Unit S2)

Sedimentary rocks within the volcanic sequence show a close spatial relationship to the termination of major periods of felsic volcanism. The most prominent zone of such sediments overlies the Nistoassini Lakes volcanics and continues beyond the limits of the present mapping to the north along the margin of the Nistoassini Lakes Pluton. Another sedimentary zone which terminates in Lower Nistoassini Lake trends southwest towards Dog Creek. Other sediments are associated with the quartz-eye rhyolite dome and other felsic volcanics in the region. Further to the south intravolcanic sediments are noticeably lacking or have yet to be mapped.

This group of sedimentary rocks consists predominantly of argillite and greywacke and in places includes banded pyritic carbonaceous argillite, sulphide and oxide facies iron formation, pyritic chert, minor tuffaceous sediments and a few mafic to felsic dykes, sills and/or flows. Lenses of barren massive sulphides, many with preserved sedimentary structures, occur near the base and top of the unit, particularly in the Nistoassini Lakes area. Iron formation is apparently absent in the south half of the area.

Argillite and greywacke (subunit S2ag) are light to dark grey on fresh and weathered surfaces, but commonly show splotchy to intense iron staining because of disseminated iron sulphides. The rocks are aphanitic to fine grained and composed mainly of quartz, feldspar and biotite, and locally porphyroblasts of hornblende, garnet and staurolite which range from less than 1 mm to 2 cm in size. Both garnet and staurolite show a marked increase in size and abundance towards the hinge zone of the major anticline west of Lower Nistoassini Lake. Preserved

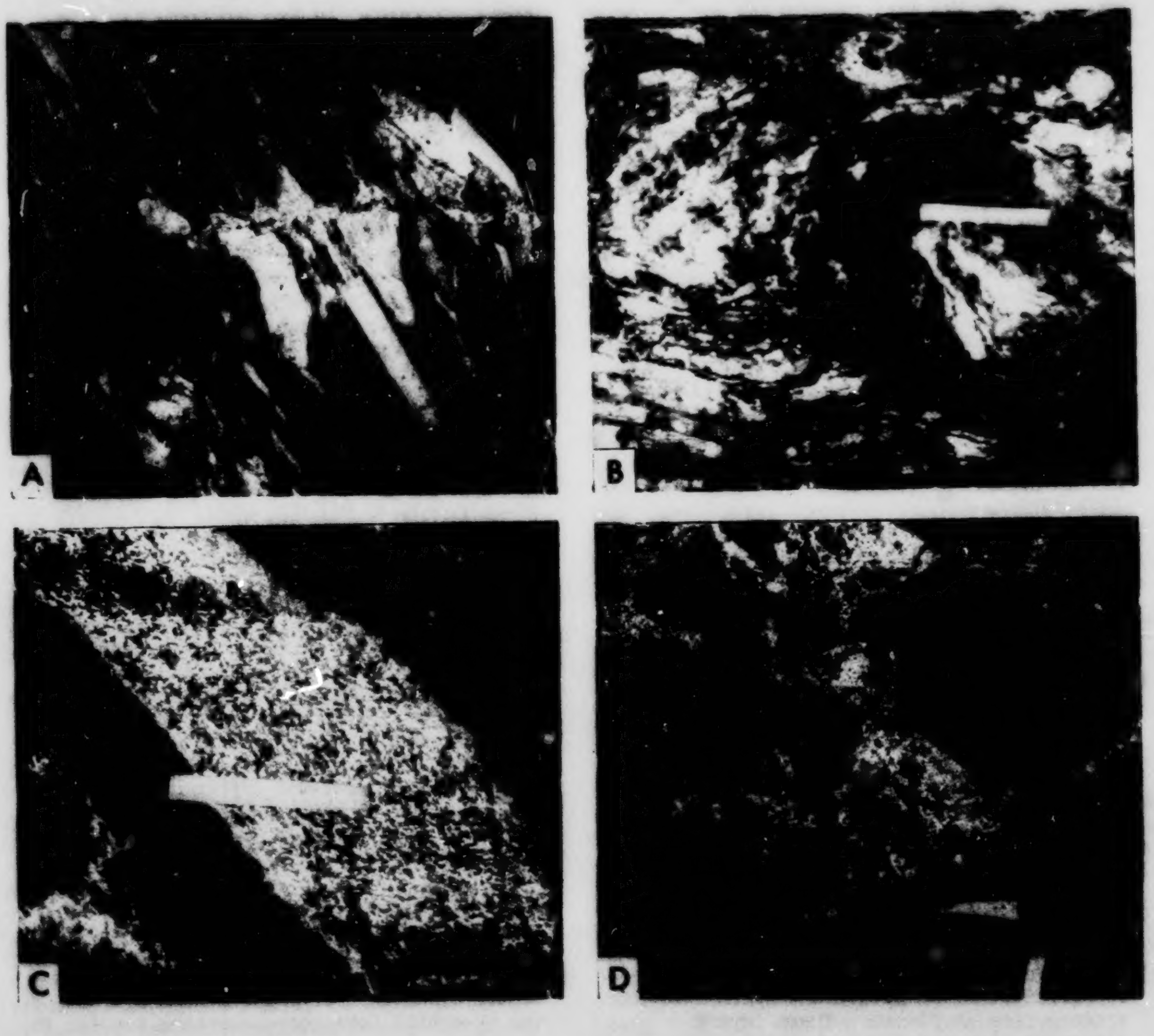

Plate 2 - A) Rhyolitic agglomerate at Kidney Lake, showing extreme elongation of the fragments; this locality is about 2 km east of that in Plate 1D; scale is 15 cm; B) Slump structure outlined by chert layers (white) in banded sulphide-carbonate-oxide facies iron formation in the Twin zone gold prospect; scale is 15 cm; C) Relict primary igneous layering in gabbro in roadside outcrop west of southwest bay of Upper Waddy Lake; scale is 15 cm; D) Intrusion breccia containing angular blocks of Dog Creek diorite (grey) encased in Upper Waddy Lake granodiorite (light grey); hammer for scale.

sedimentary structures include graded and cross-bedding, truncated beds, slump structures and delicate laminations.

The iron formation (subunit S2F) includes bedded pyritic carbonaceous argillite and chert, massive pyrrhotite and/or pyrite, and mixed sulphide-carbonate-oxide facies interlayered with chert. The bedded variety is finely laminated with alternating pyrite and quartz-rich carbonaceous layers which locally grade into massive pyrite. The pyritic argillites are normally 3 to 10 m thick, but north of Pillow Lake a 120 m section was intersected by diamond-drilling (Assessment File 64D5-SW-0060, Saskatchewan Energy and Mines, Regina). Penecontemporaneous slump structures are preserved in these sediments.

Massive sulphide lenses up to 20 m thick consist predominantly of pyrrhotite but locally alternate with pyrite or consist of massive pyrite. Accessories include chalcopyrite, sphalerite and carbonaceous material. In a few places primary sedimentary (exhalative) features are preserved in the sulphides. In such cases the sulphide shows finely laminated bedding and cross-bedding, and consists of 50 percent or more of very fine grained anhedral pyrrhotite accompanied by fine quartz, mica, carbon and sphalerite. A massive sulphide zone at the south end of Lower Nistoassini Lake contains a 1 to 2 m thick horizon of pyrite-pyrrhotite nodules up to 4 cm diameter (see Harper, 1983).

A more common type of massive sulphide has been produced by metamorphic recrystallization and brecciation of the primary type. This type consists of angular to round clasts of the primary pyrrhotite, carbonaceous argillite, chert and/or felsic tuff within a coarsely crystalline pyrrhotite matrix which contains euhedral pyrite grains up to 1 cm across.

In the vicinity of North and South Twin Lakes a mixed sulphide-carbonate-oxide facies occurs which can be traced for at least 2.5 km farther east. The rocks are fine to coarse grained, have splotchy to pervasive iron stain and consist of rather friable dark green diopside-actinolite±garnet layers 1 to 10 cm thick, which contain disseminations or thin layers of magnetite (from 5 to 30 percent), minor pyrite and pyrrhotite and arsenopyrite in places. These layers alternate with white sugary-textured chert layers of comparable thickness. In many places the iron formation is disrupted by ball and slump structures (Plate 2B) and other soft sediment structures.

Intrusive Rocks

Intrusive rocks range from pyroxenitic to granitic pegmatite, were undoubtedly intruded over a considerable time span and include dykes, sills, small stocks and multiphase batholiths.

Mafic dykes (unit M) are dark green to greenish black, aphanitic to very fine grained, range in width from 20 cm to 3 m and in the Twin Lakes area have been traced for several hundred metres along strike. Compositionally they are diabasic, but as they resemble some of the massive basaltic rocks, incompletely exposed bodies may be mistaken for flows. The mafic dykes appear to be synvolcanic and have not been found to intrude larger plutonic bodies.

A small pyroxenite (unit Px) body occurs at the mouth of the Kenwood River and two subparallel dykes occur half a kilometre west of the north end of Greenhill Lake. The rocks are poorly exposed, strongly altered, green to greenish brown and coarse grained. Original minerals are apparently entirely replaced by talc, chlorite and carbonate.

Gabbroic rocks (unit Gb) occur in several small stocks, as a possible border phase along the margin of the Nistoassini Lakes batholith in the Greenhill Lake area, and as irregular masses in the Sonya Lake diorite. The rocks are typically dark green to black, coarse grained (3 to 5 mm) and massive, but locally display primary layering, such as in the stock in the southwest bay of Upper Waddy Lake. Layering consists of alternating mafic-rich and mafic-poor zones, in which primary cumulate textures appear to be preserved (Plate 2C). The gabbroic rocks are generally composed of 40 to 50 percent metamorphic hornblende and up to 5 percent biotite, both variably replaced by chlorite. Plagioclase is the other major constituent. Relict pyroxene is preserved locally, and 1 to 2 mm long crystals of apatite are visible in the coarsest gabbros. Pyrite is a common accessory mineral and disseminated chalcopyrite is present in the Greenhill Lake body.

The small circular stock on the southeast shore of Lower Nistoassini Lake has a sheared and silicified contact with the surrounding mafic volcanics. Intrusion breccia, which occurs along part of the southern contact of the Greenhill Lake body, contains angular to rounded gabbro fragments up to 20 cm across. Bleached reaction rims occur between the fragments and the enclosing dioritic to gabbroic matrix (see Plate 15, Harper, 1983).

Diorite and quartz diorite (unit Di, QDi) occur as sills, dykes and stocks ranging from a few metres to 2 km in thickness. Parts of the border phase of the Nistoassini Lakes and Payn Creek plutons are dioritic. Diorites in the volcanic sequence are subconcordant to layering and tend to be finer grained than the larger stocks. These diorites are greenish grey to dark grey, have a 1 to 2 mm grain size and comprise 30 to 40 percent combined hornblende and biotite. The remainder of the rock is largely plagioclase, unless quartz is present. The major diorite stocks are light to dark grey, locally pinkish grey, medium to coarse grained (2 to 4 mm), mostly weakly to moderately foliated and are similar compositionally to the smaller diorites.

Fine- and coarse-grained diorite phases occur in the Sonya Lake stock, in addition to lesser amounts of gabbro and granodiorite. The Dog Creek stock is rather uniform but has been brecciated and extensively veined by younger granite and granodiorite. A portion of the contact between this stock and a younger pluton northeast of Round Lake exhibits a spectacular intrusion breccia over a 20 to 30 m width. Angular fragments, from less than 1 cm to a metre across, are encased in a granodioritic matrix (Plate 2D).

Granodiorite (unit Gd), quartz monzonite (unit QM) and granite (unit G) comprise the major plutons and a number of smaller stocks in the area. Some of the plutons, such as the Nistoassini Lakes Pluton are multiphase or zoned, having compositions that range inwards from dioritic to granitic. Other prominent variations include colour, texture, degree of foliation and relative abundance of mafic minerals. Eight intrusive bodies were recognized and are described separately here.

The Nistoassini Lakes pluton in the northeast (see accompanying maps) has two main and two lesser phases: 1) granite-quartz monzonite, 2) granodiorite, 3) diorite and 4) gabbro. From the northeast towards the volcanics this pluton changes gradationally from a white, pink and pinkish-grey, coarse-grained (4 to 6 mm) foliated granite-quartz monzonite, which contains 5 percent or less biotite, to a light to pinkish-grey weathering coarse-grained (2 to 4 mm), strongly foliated granodiorite, which contains about 10 percent each of hornblende and biotite. The biotite content increases steadily to about 10 or 12 percent before hornblende begins to appear in the rocks, followed by a rapid increase to about 10 percent. Concurrently quartz decreases from 30 to 15 percent. In several places the change from granite to granodiorite is also marked by a change in the dip direction of the foliation; they dip towards each other. Near the volcanics the mafic content generally increases to as much as 30 percent, with hornblende dominant. Xenoliths, which occur throughout, are more abundant closer to the margin of the pluton, and include mafic and felsic volcanic rocks. Many of these xenoliths have a dioritic appearance, possibly the result of thermal metamorphism of mafic volcanic inclusions. A few pegmatite and aplite veins intrude the pluton.

The Contact Lake pluton occupies the east-central part of the area and much of Lower Waddy Lake. This body varies from granodioritic near the margin to granitic toward the centre. The rocks are pink to pinkish grey, coarse grained (2 to 4 mm), very strongly foliated at the margin and less strongly foliated inwards. Biotite content is about 15 percent at the margin and decreases to 3 to 5 percent within one kilometre of the contact. For the first few metres in from the northern margin the rock is densely packed with rounded flaggy xenoliths of the lower sedimentary rocks (unit S). Elsewhere only scattered amphibolitic xenoliths are found. Pink granite pegmatite veins intrude the granite.

A possible lobe of the Contact Lake pluton crops out along the west shore of Lower Waddy Lake. The granitic rocks are very strongly deformed and interlayered as well as interfolded with the volcanic rocks, which suggests that the 'lobe' may be a separate and older body. Composition ranges from hornblende-biotite quartz diorite to hornblende-biotite granodiorite to biotite granite. The rocks are fine to coarse grained (1 to 3 mm), strongly foliated, pink, light to dark grey and pinkish grey, and are cut by numerous quartz veins.

The Payn Creek pluton, which occurs in the south (see accompanying map), is generally granitic to quartz monzonitic, but is granodioritic and dioritic in places along the northern margin. To the south the pluton contains up to 10 percent K-feldspar megacrysts from 2 to 10 cm across. The granite is generally white weathering, light grey to pinkish grey on fresh surfaces, has a coarse grain size (3 to 6 mm), and is well foliated but becomes less foliated to the south. Minerals present include 25 to 30 percent quartz, 5 to 10 percent biotite and up to 2 percent magnetite, the remainder being feldspar (dominantly K-feldspar). Where magnetite is abundant, the quartz grains are commonly stained red giving the rock a distinctive red spotted appearance. Biotite occurs in aggregates up to 1 cm across and 1 to 2 mm thick.

The Kenwood Lake pluton crops out in the northwest and further west has been mapped as granite and granodiorite (Miller, 1949) and diorite (Gracie, 1965). A narrow strip of the pluton examined along its southeastern margin consists of hornblende-biotite granodiorite. The rocks are light grey and pinkish to reddish grey on fresh and weathered surfaces, coarse grained (3 to 4 mm), well foliated and contain up to 20 percent hornblende and biotite.

The Boundary Lake pluton, located in the west, was only examined along parts of the eastern margin and was found to vary from diorite to granite. In the north this pluton has distinctive blue quartz eyes which were also observed farther west in this pluton by Miller (1949), who mapped these rocks as a quartz monzonitic phase. The blue quartz-eye quartz monzonite encountered this summer is pink weathering, pinkish grey on fresh surfaces, coarse grained (2 to 6 mm), generally massive, and comprises 20 to 30 percent quartz, 60 to 70 percent feldspar (about equal proportions of K-feldspar and plagioclase) and up to 10 percent biotite. The blue quartz eyes are 2 to 6 mm in diameter and generally subhedral.

The diorite-granodiorite phases are mottled light to dark grey and reddish-grey weathering, fine to medium grained, and massive to weakly foliated. Biotite and hornblende comprise 10 to 40 percent of these rocks and in places the diorite contains up to 5 percent quartz.

The Upper Waddy Lake stock, which varies from granodiorite near the margin through to granite, crops out along the west shore and on several islands of Upper Waddy Lake. It intrudes the earlier emplaced Dog Creek diorite-quartz diorite as described above. The rocks are pink to light grey on fresh and weathered surfaces, fine to coarse grained (1 to 3 mm), and weakly foliated near the margin but becoming massive inwards. Biotite is the dominant mafic mineral, ranging from 5 to 10 percent, whereas hornblende is more prevalent near the margins where the stock intrudes diorite and mafic volcanics, and comprises up to 10 percent of the rock. Quartz is clear and increases from 10 percent near the margin to about 30 percent near the core.

The Round Lake stock is one of a group of smaller recessive weathering 'granitic' stocks which underlie small lakes and muskegs in the area west of Waddy Lake. The surface expression of the Round Lake stock consists of a few outcrops and frost-heaved boulders along its margin. It consists dominantly of a pink- to grey-weathering, fine- to coarse-grained (1 to 4 mm), massive to weakly foliated leucogranite with distinctive blue quartz. These rocks contain 25 to 30 percent, and locally as much as 40 percent quartz, 50 to 70 percent feldspar with K-feldspar dominant and generally less than 5 percent biotite. The youngest phases of this stock consist of veins and dykes of pink to light grey, coarse-grained, quartz monzonite/granite, pink fine-grained aplite and a distinctive bluish-grey coarse-grained blue quartz granite. The quartz phenocrysts are up to 6 mm across and comprise up to 20 percent of the rock. These veins and dykes are very prevalent at the Komis gold deposit and occupy northeast-trending fracture zones which are approximately perpendicular to the granite-volcanic contact. Porphyritic granite veins/dykes lie parallel to this contact along the northeast margin of the stock.

Smaller granodiorite to granite stocks occur west of Waddy Lake, underlying Kidney, Earl, Corner and Bean Lakes[1]. The shape of Oven Lake and the apparent displacement of the volcanics around the lake suggests that Oven Lake is also underlain by a small stock. A slightly larger stock crops out south of the large southwest bay of Upper Waddy Lake. Typically these stocks are exposed in a few scattered outcrops around the edges of the lakes and coincide with a northwest-trending aeromagnetic low (Geological Survey of Canada, 1964). Several are closely associated with small gold showings. Feldspar porphyry dykes are noticeably more abundant in the vicinity of these stocks and thus may be related. The stocks are pink to pinkish grey, medium to coarse grained, massive or very weakly foliated and several contain up to 40 percent K-feldspar phenocrysts.

Granite pegmatite (unit P) occurs in the south where two large dykes intrude the 'ultramafic volcanic sequence'. According to Byers (1948) they also intrude granitic rocks further south.

The larger of the dykes is a garnet-muscovite pegmatite (subunit Pgm), up to 100 m thick, which is white weathering and massive except in a 20 to 40 cm thick zone along its margin where it is commonly sheared. The coarsest part of the body occurs at its northern end. Garnet, most abundant within several metres of the contact, suggesting contamination by adjacent magnesium-rich volcanics, occurs as euhedral crystals from a few millimetres to one centimetre in diameter. Muscovite is distributed throughout, occurring as euhedral books 5 mm in diameter in subgraphic intergrowth with quartz. Large books up to 8 cm long by 3 cm thick and sheaf-like intergrowths with quartz up to 10 cm across also occur. Rare pink microcline crystals up to 30 to 40 cm across and metre-sized masses of quartz also occur in places.

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[1] unofficial lake names

The smaller dyke is a tourmaline-bearing granite pegmatite (subunit Pt) which averages 5 m in width and is white weathering, medium to very coarse grained (2 mm to 5 cm) and weakly foliated. The pegmatite generally comprises equigranular quartz and feldspar but in places contains feldspar crystals up to 5 cm across. Strongly-oriented needle-like crystals of black tourmaline less than 5 mm long comprise 2 to 3 percent of the rock. Muscovite is also present.

Iron-Cemented Till and Bog Iron Ore

Surficial deposits of iron-cemented till and bog iron ore (marked with an asterisk (*) on the accompanying maps) occur in low swampy areas adjacent to or overlying many of the sulphide zones. The till consists of poorly sorted heterolithic angular to rounded pebbles and cobbles in a granular to clayey matrix which has been replaced by limonite-geothite. Many of the fragments are highly weathered and crumble upon exposure. The cemented till provides a well-indurated crust as much as 0.5 m thick, directly overlying sulphides.

The bog iron ores comprise poorly consoliated powdery to nodular deposits of limonite-geothite which tend to replace organic matter and clayey material in low and swampy ground. Subaerially exposed bog ores are poorly vegetated and yellowish to reddish brown, whereas subaqueous bog ores underlie shallow sulphurous-smelling ponds.

Structure

Primary features helpful in determining tops and indicating major folds include graded and cross-bedding, scour-and-fill and slump structures, flow contacts, flow top breccias and pillow lavas. Throughout most of the area a finely developed tectonic foliation (S_1) parallels the original bedding and volcanic layering (S_0), but numerous places also exist where S_1 is oblique or perpendicular to original layering.

The La Ronge Domain is dominated by regional northeasterly strikes. Locally the earliest fold structures (D_1) display a variety of axial traces, plunges and styles, including isoclinal, arcuate and triangular patterns, depending on the size, shape and proximity of plutonic bodies. The 'triangular folds' resemble pressure shadows on a large scale, a style typical of greenstone belts (Gorman et al., 1978; Condie, 1981).

A younger set of folds (D_2) manifests itself as small-scale northeast-trending crenulation and kink folds which have steep plunges to both the northeast and southwest. A subvertical axial planar cleavage and penetrative foliation (S_2) is developed in the hinge zones of these small-scale folds.

The degree of deformation varies across the Waddy Lake area from zones of low strain, where primary structures and textures are essentially undeformed, to zones of extreme strain where the rocks are strongly and sometimes intensely lineated and foliated; fragments are stretched and flattened with maximum strain ratios in excess of 10 to 1 (R. Kasmirski, 1984, pers. comm.) and late granite veins are boudinaged and folded. These zones of high strain commonly occur 1) in major fold hinges where the supracrustal rocks are squeezed between larger plutons, 2) along the margins of most of the plutons, 3) in 'pressure shadow' regions of small stocks, and 4) adjacent to major shear zones.

The trace of the most prominent shear zone in the area, the southwesterly- to westerly-trending Byers Fault, is generally marked by a muskeg- or lake-filled lineament. The fault and associated shear foliation dip to the north. The hanging wall side is intensely sheared in a narrow zone immediately adjacent to the fault, whereas the footwall side has a gradational zone of shearing over several hundred metres wide. Besides the shearing directly associated with the fault, the zone is characterized by a strong penetrative foliation to submylonitic fabric and strongly developed northerly-plunging lineation. Quartz veining occurs parallel to and in second-order faults of the main fault. The amount and sense of movement along the fault has not been determined.

Several other subparallel northeast-trending faults, characterized by narrow shear zones several metres to tens of metres wide, occur to the north and south of the Byers Fault. Northwest- to north-northwest-trending linear topographic features interpreted as late brittle faults appear to offset rock units locally and are of limited strike length. Concentric and apparent subradial shears and faults are developed around some of the stocks and plutons.

Metamorphism

The regional metamorphic grade is upper greenschist to lower amphibolite facies. Grade generally increases towards the margins of the volcanic-sedimentary complex. Grade also increases to upper amphibolite facies towards the hinge zones of major folds (as for instance in the southwest-trending anticlinal closure west of Lower Nistoassini Lake and in metamorphic aureoles around many of the larger plutonic bodies).

Diagnostic minerals of the upper greenschist-lower amphibolite facies transition include chlorite, actinolite, biotite, blue green hornblende, garnet and staurolite. Much of the observed chlorite is prograde but some is due to retrometamorphism, as chlorite partially replaces hornblende, biotite and less commonly garnet. With increasing regional grade, pleochroism in hornblende changes from blue-green to green.

Contact metamorphic aureoles, generally up to 100 m wide, surround many of the plutons. They are characterized by a coarsening of grain size, increased amounts of granitic neosome and a more gneissic character. In most places the grade seems to be middle to upper amphibolite facies. The highest grade rocks observed are sillimanite-garnet-bearing pelitic rocks adjacent to the Contact Lake pluton.

Lithogeochemistry

A lithogeochemical program was initiated in cooperation with the University of Regina (see Watters, this volume). A preliminary analysis of the results obtained to date indicates that most rocks have a tholeiitic affinity (Jensen, 1976) in contrast to a general calc-alkaline affinity for the La Ronge Domain. The ultramafic volcanic suite at the south end of Lower Waddy Lake has a komatiitic-like trend (Fox and Johnston, 1981). Further discussion on these and other aspects of the lithogeochemical program must await completion of the data analyses.

Age Relations and Geologic History

A U-Pb zircon geochronology study initiated in 1983 (Bickford et al., 1983) was continued this field season (Bickford et al., this volume). All of the major plutons, several smaller stocks and some of the rhyolites were sampled during the current field season by the University of Kansas personnel. The following is an interim summary of geologic events in the Waddy Lake area.

A basement to the volcanosedimentary complex has not been identified and may not be exposed in the Waddy Lake area. The oldest rocks so far identified are the lower sediments (unit S). The presence of volcanic clasts in conglomerates of this unit indicates that volcanic source rocks were present and may suggest that volcanism was in part contemporaneous with deposition of the sediments. The early clastic sedimentation was apparently terminated by extrusion of ultramafic magnesium-rich flows in the southern part of the area. Elsewhere equivalent sediments may be overlain by magnesium- and iron-rich basaltic flows, some of which may have komatiitic affinity. Preliminary geochemical analyses suggest that volcanism followed a komatiitic to tholeiitic trend, progressing from magnesium to high iron tholeiitic basalts, then to tholeiitic andesite and finally to tholeiitic rhyolites. Volcanism of calc-alkaline affinity occurred locally . Previous geochemical studies (Harper, 1983) suggest that calc-alkaline volcanism was more prevalent in the Nistoassini Lakes area and culminated in extensive felsic pyroclastic volcanism followed by prolonged iron-rich exhalative activity. This period was also accompanied by a second major period of sedimentation.

Plutonism has occurred over a considerable span of time. Synvolcanic dykes and sills of similar composition to the host volcanics occur at all levels in the volcanic pile. The proximity of blue quartz-eye rhyolites and blue quartz-bearing granitic rocks of the Boundary Lake pluton and the Round Lake stock strongly suggests a close temporal relationship between the extrusive and intrusive rocks. The major plutons appear, on the other hand, to have been largely emplaced later during tectonism.

Uranium-lead zircon ages obtained thus far indicate felsic volcanism occurred about 1930 Ma and that the major plutonism occurred at about 1880 Ma, coincident with the peak of Hudsonian orogenesis (Van Schmus, 1984, pers. comm.). Since several cycles of felsic volcanism are possible and the earliest cycle was preceded by ultramafic through to intermediate volcanism, the intitiation of volcanic activity must predate 1930 Ma.

Economic Geology

Large iron sulphide-bearing zones were discovered as early as 1928 in the Nistoassini-Waddy Lakes area (Alcock, 1938; Byers, 1948). They have been re-examined many times since then for their base metal, gold and iron potential. The first reported discovery of gold was in 1947 at the north end of Upper Waddy Lake by prospectors working for Consolidated Mining and Smelting Company of Canada Ltd. (Byers, 1948), but by the mid-fifties interest had declined. The dramatic rise in the price of gold in the seventies prompted the present resurgence of exploration activity in the La Ronge volcanic belt and re-examination of all known gold showings in the Waddy Lake area. This activity led to the discovery of several new gold showings, notably the Twin and EP Zones.

Sulphide Mineralization:

The sulphide occurrences are well described by Byers (1948), Beck (1959) and Harper (1983). Sulphide mineralization occurs as disseminations, veins and nodules of pyrite and pyrrhotite, as well as bedded and massive sulphide-facies iron formation. Disseminated pyrite and less commonly pyrrhotite are present locally in most rock types throughout the area, and form haloes around the massive sulphide lenses. Pyritic haloes are also associated with some of the known gold mineralization, as for example at the Komis, Weedy and Kidney prospects. A few occurrences of disseminated chalcopyrite were found during the present mapping, particularly along the margin of the western lobe of the Contact Lake pluton. Chalcopyrite also occurs in the gabbroic rocks at Greenhill Lake and along with sphalerite is a common but minor component of the bedded and massive sulphides. Barren veins of pyrite and pyrrhotite occur in the brecciated rhyolites north of Kenwood River and the bedded and massive sulphide deposits, the latter reflecting mobilization of the sulphides during deformation and metamorphism.

A siliceous stringer-type zone of pyrite accompanied by a few percent chalcopyrite and silver-bearing galena occurs in dacites and rhyolites west of Earl Lake. Grab samples collected by Hydra Explorations Ltd. in 1961 returned assays of 0.02 oz./ton (0.7 g/tonne) Au and 0.90 oz./ton (31 g/tonne) Ag (Assessment File 64D04-NE-0003, Saskatchewan Energy and Mines, Regina). The felsic volcanic host rocks, siliceous alteration and stringer-type mineralized zone bear some resemblance to Kuroko-type mineralization (Kuroda, 1983; Urabe et al., 1983).

The character and distribution of the bedded and massive sulphide deposits has already been described. The soluble iron content of these sulphide zones ranges from 5.70 percent over 3 m to 39.4 percent over 3 m, with grab samples yielding as much as 42 percent Fe (Harper, 1983). One 24 m section averages 23.25 percent Fe and 3.54 percent C. Sporadic disseminated chalcopyrite and sphalerite are found in the sulphide zones, as are negligible to trace amounts of gold.

The only significant base metal-gold mineralization associated with the sulphide mineralization is the Churchill Minerals zone lying between Pillow and Lower Nistoassini Lakes. Trenching and diamond-drilling, principally by Hudson Bay Mining and Smelting Co. Ltd., outlined a small uneconomic copper deposit (Assessment Files 64D05-SW-0003, -0052 and -0060, Saskatchewan Energy and Mines, Regina). Mineralization, apparently plunging steeply to the west, was encountered over a 250 to 300 m strike length and over widths of up to 12 m to a depth of 250 m. Better mineralized sections from deep drilling in 1974 by Hudson Bay Exploration and Development Co. Ltd. returned assay values of 0.93 percent Cu and 0.1 percent Zn over a true width of 8.3 m at a depth of 250 m (hole Vet 14-W-1). About 40 m above this in the same hole, a 90 cm section assayed 0.78 oz./ton Au and 1.0 oz./ton Ag with 0.5 percent Cu and 0.2 percent Zn (Assessment File 64D05-SW-0060, Saskatchewan Energy and Mines, Regina).

The stringer-type mineralization at Earl Lake is the only known base metal sulphide occurrence away from the Nistoassini Lakes zone of sulphide mineralization. Unlike the latter area, sediments and iron formation are not presently known in the Earl Lake area. The stringer-type mineralization may, however, be an indicator of base metals.

Gold Mineralization:

In the Waddy Lake area, gold typically occurs in and adjacent to quartz veins, many of which occur within or marginal to intrusive rocks, such as gabbro (Greenhill Lake), diorite (Weedy Lake, Wedge Lake, Upper Waddy Lake) and granite (Komis, Kidney Lake, Corner Lake). At least two quartz vein-hosted occurrences are associated with shear zones cutting ultramafic (VG) to mafic (Upper Waddy Lake) basalts. The veins occur in both the intrusive and extrusive rocks, and are commonly surrounded by pyritized wall rocks which contain elevated to ore grade concentrations of gold. The mineralized structures tend to fall into two or three patterns: 1) fracture zones subradial to host or adjacent intrusive stocks; 2) fracture zones subparallel (concentric) to the margins of the intrusive stocks, and also possibly subparallel to the layering; and 3) fracture zones subparallel to major regional faults (e.g. Byers Fault) and cutting both intrusive and extrusive rocks.

The bedded and massive sulphide facies iron formations have only yielded trace amounts of gold, but gold concentrations are elevated where base metal concentrations are elevated, as at the Churchill Minerals occurrence. The recent surge of exploration activity led to the discovery of gold values of economic interest in the iron formation at Twin Lakes. This iron formation is a combined sulphide-carbonate-oxide facies type with sporadically distributed arsenopyrite.

Beck (1959) summarized the geology and exploration work carried out on the known gold occurrences in the Waddy Lake area up to the mid-fifties. Coombe (1976) and Johnston (1981) have briefly described the character of the Komis deposit. The following brief descriptions summarize recent published information and include some of the author's observations.

The Komis zone, presently held in joint venture by Waddy Lake Resources Inc. (75 percent) and Energy Reserves Canada Ltd. (25 percent), was discovered by E.F. Partridge in 1958. The property has undergone extensive exploration including more than 8000 m of diamond-drilling and bulk sampling for mill testing. The Komis zone contains drill-indicated and probable ore reserves of 1.46 million t (1.6 million tons) grading 3.8 g/t (0.122 oz./ton) gold to a depth of 180 m (600 feet) (Northern Miner, 1984a,b). Estimated additional possible reserves to 400 m depth are 1.54 million t (1.7 million tons) of similar grade material. A prefeasibility study completed in 1983 concludes that the presently known reserves are amenable to open pit mining at a mill rate of 450 t/day (500 tons/day) over a seven year period at an average cost of $2.58 per g ($88.00 per oz.) of gold produced. This study did not, however, include the potential reserves of the deep Komis ore, the nearby auriferous tills, or the EP zone discovered in 1983.

The andesitic and dacitic volcanics of the Komis zone are cut by northeast-trending fracture zones as well as by granodiorite, granite and aplite veins related to the Round Lake stock. Quartz veins up to 1 m in width which cut all the rocks are typically surrounded by pyritized haloes. A second set of mineralized structures parallels the granite-volcanic contact and appears to be stratigraphically controlled, coinciding with andesitic volcanics. Gold occurs free in the quartz veins and in pyrite in the wall rocks. The pyrite occurs as cubes, 1 to 10 mm in size, locally comprising up to 15 percent of the rock. Trace amounts of chalcopyrite are present. Grab samples of heavily pyritized andesite gave values of 1100 and 8200 ppb Au (up to 0.26 oz./ton) and elevated Cu concentrations (258 and 322 ppm).

An auriferous glacial dispersion train, which contains sections grading over 120 g/t (4 oz./ton) Au (Northern Miner, 1983a), is located about 200 m east of the Komis zone. The source of the anomalous tills, the EP (Partridge) zone was located by diamond-drilling in November 1983. Drilling to the end of 1983 gave very encouraging results (see Northern Miner 1983b, 1984a). The EP Zone occupies a gently dipping zone of shearing, chloritization, felsic dyke emplacement and quartz veining which cuts andesitic and rhyolitic volcanics. The quartz veins contain free and visible gold, native copper, pyrite and galena, along with molybdenum and silver minerals (Netolitsky, 1983; Sibbald, 1984, pers. comm.).

The Weedy Lake property was discovered in 1948 by Cominco prospectors, who outlined three zones, the A, B and C, consisting of quartz veining within small quartz diorite intrusives and adjacent volcanics. The area encompassing the three zones is presently held under joint venture by Golden Rule Resources Ltd. and the Saskatchewan Mining Development Corporation.

The 'A' zone consists of a small but impressive zone of quartz veining near the north end of a small quartz diorite body. The enclosing diorite has been pyritized and hornblende is replaced by biotite. Gold values were found in both the quartz veins and altered wall rocks but are characteristically low (Beck, 1959; Netolitzky, 1983).

The 'B' zone occurs on the hill immediately west of Weedy Lake. The zone is characterized by shear-controlled quartz veins that parallel the Byers Fault and are subparallel to the long axis of a small hornblende diorite stock or sill. Gold occurs in the quartz veins and in the adjacent altered wall rocks which are silicified, chloritized, pyritized and locally carbonatized. Chalcopyrite occurs sporadically in the veins and altered wall rocks. Drill-inferred reserves of 900,000 t grading 4 g/t (0.116 oz./ton) Au to a depth of 100 m have been outlined over an oval-shaped area 350 m long and up to 60 m wide (Golden Rule Resources Ltd., 1984a). Surrounding this zone is a 600 by 100 m envelope of low-grade material which averages about 1.9 g/t (0.055 oz./ton) Au.

The 'C' zone, which lies 30 m north of the B zone, consists of several subparallel shear zones which cut the diorite and andesitic and felsic volcanics (Beck, 1959). The gold-bearing quartz veins are more confined than in the B zone but they are much higher grade with values as high as 24.5 g/t (0.714 oz./ton) Au over 4.1 m (Golden Rule Resources, 1984a, 1984b; Netolitzky, 1983). The zone has been tested over a strike length of 250 m and is still open at both ends. Tonnage and grade figures have not been released at this time.

The Twin Lakes zone, which is located about 2 km south-southeast of Upper Nistoassini Lake, was discovered in 1981 during re-examination of the Wedge Lake group of gold-bearing quartz veins trenched in the early fifties. The new discovery is an auriferous sulphide-carbonate- oxide facies iron formation with sporadically disseminated arsenopyrite, but without the quartz veining typical of other showings in the immediate vicinity. The gold is believed to be of primary exhalative origin. The iron formation is complexly folded and apparently disrupted by later faulting which separates the mineralization into two steep westerly plunging zones. Drill-indicated reserves are in excess of 600,000 t, averaging 5.1 g/t (0.15 oz./ton) Au to a depth of 75 m (Golden Rule Resources Ltd., 1984a).

The Kidney, Corner and Oven Lakes prospects contain narrow typically east-northeast-trending pyritized shear zones accompanied by quartz veining as well as close spatial association with possibly late granitic stocks. Elevated gold concentrations occur in the quartz veins and pyritized wall rocks which include mafic to felsic volcanic and granitic stocks and veins.

References

Alcock, F.J. (1938): Reindeer Lake South map-area, Saskatchewan; Geol. Surv. Can., Pap. 38-15.

Beck, L.S. (1959): Mineral occurrences in the Precambrian of northern Saskatchewan (excluding radioactive minerals); Sask. Dep. Miner. Resour., Rep. 36p.

Bickford, M.E., Lewry, J.F. and Van Schmus, W.R. (1983): Zircon isotope geochronology project: U-Pb (zircon) chronology for the Hudsonian orogenic terrains in Saskatchewan; Sask. Geol. Surv., Misc. Rep. 83-4, p34-39.

Byers, A.R. (1948): The geology of the Waddy Lake area, Rottenstone Mining Division, Saskatchewan (preliminary report); Sask. Dep. Miner. Resour., Rep. 1.

Condie, K.C. (1981): Archean Greenstone Belts; Developments in Precambrian Geology, Vol.3; Elsevier Scientific Publishing Co., N.Y., 434p.

Coombe, W. (1976): La Ronge - Wollaston base metals project; in Summary of Investigations, 1976, Sask. Geol. Surv., p99-103.

Fox, J.S. and Johnston, W.G.Q. (1981): Komatiites, "boninites" and tholeiitic picrites in the central La Ronge metavolcanic belt, Saskatchewan and Manitoba and their possible economic significance; CIM Bull., July, p.73-82.

Geological Survey of Canada (1964): Waddy Lake (NTS 64D-4), Aeromagnetics; Geol. Surv. Can., Geophys. Pap. 2840G, scale 1:63,360.

Golden Rule Resources Ltd. (1984a): Annual Report, 1983.

______________________ (1984b): Interim report to shareholders.

Gorman, B.E., Pearce, T.H. and Birkett, T.C. (1978): On the structure of Archean greenstone belts; Precambrian Res., v6, p23-41.

Gracie, A.J. (1965): The geology of the Hickson Lake area (east half), Saskatchewan; Sask. Dep. Miner. Resour., Rep. 100.

Harper, C.T. (1974): Northern iron ore exploration; in Summary Report of Field Investigations, 1974, Sask. Geol. Surv., p78-83.

__________ (1976): Northern iron ore exploration; in Summary of Investigations 1976, Sask. Geol. Surv., p104-114.

__________ (1983): Iron ores of northern Saskatchewan; Sask. Energy Mines, Rep. 220.

Jensen, L.S. (1976): A new cation plot for classifying subalkalic volcanic rocks; Ont. Geol. Surv., Misc. Pap. 66.

Johnston, W.G.Q. (1969): The geology of the eastern portion of the Waddy Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 127.

______________ (1970): The geology of the Hay Lake area (east half), Saskatchewan; Sask. Dep. Miner. Resour., Rep. 130.

____________ (1981): Gold metallogenic studies: Waddy Lake and region; in Summary of of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p92-96.

Kirkland, S.J.T. (1959): The geology of the Brabant Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 33, 31p.

Kuroda, H. (1983): Geologic characteristics and formation environments of the Furutobe and Matsuki Kuroko deposits, Akita Prefecture, northeast Japan; in The Kuroko and Related Volcanogenic Massive Sulphide Deposits; Econ. Geol., Mono. 5, p149-166.

Miller, M.L. (1949): The geology of the Windrum Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 3.

Muffler, L.J.P., White, D.E. and Truesdell, A.H. (1971): Hydrothermal explosion craters in Yellowstone National Park; Geol. Soc. Am. Bull., v82, p723-740.

Netolitzky, R.K. (1983): Developments in Saskatchewan gold exploration: unpubl. paper presented at 89th Annu. Northwest Min. Assoc. Conv., Spokane.

Northern Miner (1983a): Waddy Lake gets positive results; Nov. 10, p3.

____________ (1983b): Waddy Lake drilling expands new zone; Dec. 22, p7.

____________ (1984a): Waddy Lake prefeasibility considers milling and heap-leach; Feb. 2, p3.

____________ (1984b): Financing negotiations continuing, Waddy says; June 21, p7.

Urabe, T., Scott, S.D. and Hattori, K. (1983): A comparison of footwall alteration and geothermal systems beneath some Japanese and Canadian volcanogenic massive sulphide deposits; in The Kuroko and Related Volcanogenic Massive Sulphide Deposits; Econ. Geol., Mono. 5, p345-364.

Watters, B.R. (1981): Geochemistry of metavolcanic rocks in the La Ronge Domain; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p34-37.

Project 8412

Geological Mapping, Star Lake Area (part of NTS 73P-16 and 74A-1)

by D.J. Thomas

Thomas, D.J. (1984): Geological mapping, Star Lake area (part of NTS 73P-16 and 74A-1); *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The geology of an area comprising about 120 km^2 and covering portions of NTS sheets 73P-16 and 74A-1 was mapped this summer at a scale of 1:20,000. The area is accessible by float-equipped aircraft from La Ronge or Missinipe, 115 km and 55 km to the south respectively. Highway 102 allows limited access to the southeastern part of the map sheet. Existing drill roads, as well as an unmaintained mine road traversing the area between Highway 102 and Mallard Lake, are presently unsuitable for use by conventional road vehicles.

The area has a relatively low relief, ranging from 10 to 30 m or, in some places, as much as 50 m above the lake levels. Lakes are relatively small and shallow. Exposed bedrock is relatively abundant but is inconveniently obscured by a thick blanket of moss.

The earliest recorded geological mapping in the area by the Geological Survey of Canada in the mid 1930's (McLarty, 1936; McMurchy, 1938), identified a northeast- trending belt of metamorphosed volcanic and sedimentary rocks intruded by a variety of plutonic rocks. Further geological mapping at 1:63,360 scale between 1949 and 1965 (Miller, 1949; Budding, 1955; Morris, 1961; Gracie, 1967) verified the presence of metavolcanics and lesser amounts of metasediments, and refined the petrography of the intrusive rocks. Recent work in the area includes lithogeochemical studies of the metavolcanics (Watters, 1981), regional tectono-stratigraphic relations (Lewry et al., 1980; Lewry, 1983) and geochronology studies (Bickford et al., 1983).

The first significant mineral exploration activity in the Star Lake area, undertaken by the Consolidated Mining and Smelting Co. of Canada Ltd. immediately following World War II, led to the discovery of the majority of the gold prospects presently known in the La Ronge Domain. D.R. Whitmore of Consolidated described the geology of the Star Lake area in 1947 (Assessment File 73P-16-NW-0003, Saskatchewan Energy and Mines, Regina).

The discovery in the early 1960's of auriferous quartz veins related to shear zones between Star Lake and Fork Lakes led to the staking of the Kahn claim group by Eric Partridge (independent prospector). A similar discovery northeast of Star Lake made by Eugene and Mary Hird (independent prospectors) was staked as the Pie claim group and was later followed by an attempt at high-grading on the property with the aid of a portable crusher. Between 1973 and 75, Decade Development Ltd. unsuccessfully attempted a mining-milling venture on the original Jolu prospect at Mallard Lake.

The most recent activity in the area is proceeding on the Star Lake joint venture, a partnership between Starrex Mining Corporation (50 percent) and Saskatchewan Mining Development Corporation (50 percent) at the northeast end of David Lake (about 700 m east of Star Lake). An environmental, mining and ore-processing feasibility study is currently in progress for this property (SMDC news release, July 16, 1984).

Mahogany Mineral Resources Inc. completed geochemical, prospecting and diamond-drill programs during this past summer on their Mallard Lake property and recently announced a major exploration and development program for 1985 (Mahogany Minerals Resources Inc. news release, August 20, 1984).

Regional Background and General Geology

The study area lies along the eastern portion of a northeasterly trending linear belt formally referred to as the La Ronge Domain (Macdonald and Broughton, 1980; Lewry, 1983). The belt is divided into an eastern part underlain predominantly by metavolcanics with lesser volcanogenic-derived metasediments and a western part mapped as largely clastic metasediments. The supracrustal rocks have been intruded by pretectonic to post-tectonic basic to acid rocks. The southeastern part of the present map area includes feldspathic metasediments belonging to the McLennan Group (Lewry, 1983) in the MacLean Lake Belt (Macdonald and Broughton, 1980). The junction between the volcanic-plutonic rocks of the La Ronge Domain and 'arkosic' metasediments of the McLennan Group is marked by cataclasis.

Five broadly defined rock types occur in the Star Lake area: 1) metavolcanics, 2) metasediments, 3) basic intrusives, 4) intermediate to acid intrusives and 5) 'tectonites'.

Metavolcanics and Metasediments

Although the metavolcanic-sedimentary succession is characterized by rapid lateral and vertical facies changes throughout, some broad generalizations on the distribution of rock types and lithostratigraphic relations were established from the mapping:

1) Volcanic rocks are dominantly of pyroclastic nature, ranging from tuff-breccias and agglomerates through lapilli tuff to ash tuff deposits. Pyroclastics are interlayered with lesser amounts of flow-type rocks of predominantly mafic to intermediate composition. Felsic flows locally occur at Jojay Lake and south of Star Lake.

2) The central part of the volcanic belt between Star Lake and Katty Lake comprises rocks of mafic to intermediate[1] composition which grade south and north into more intermediate to felsic volcanics. The volcanic assemblages underlying the area between Neyrinck and McLennan Lakes are primarily intermediate to mafic flows with lesser pyroclastics and rare sediments. Volcanics north of Island Lake are predominantly subaqueous mafic to intermediate flows intercalated with lesser intermediate to felsic pyroclastics, and volcanogenic-derived metasediments.

3) Finer grained intermediate to felsic pyroclastic deposits are increasingly intercalated and indistinguishable from volcanogenic metasediments northeast of Jojay Lake, southwest of Star Lake and east of Alpat Lake.

4) Metagreywacke-siltstones containing pyrite and local graphite commonly occur proximal to the metasedimentary-volcanic transition.

5) Limited way-up evidence indicates a prevailing 'younging' direction towards the west and northwest. At least 2900 m of underlying volcanics and possibly up to 2500 m of volcanogenic sediments are estimated to be present. Basement rocks were not recognized.

6) Greywacke-siltstone type sediments west of Alpat Lake and feldspathic arenites along McLennan Lake appear to have been largely derived from nonvolcanic lithologies.

Mafic Metavolcanic Rocks (Unit 1):

Rocks identified as mafic metavolcanics, including pyroclastics and flows, comprise approximately 35 percent of the metavolcanic-sedimentary succession in the Star Lake area. The rocks are identified chiefly on the basis of their relative colour index, defined as having greater than 35 percent mafic minerals (clinopyroxene, amphibole, chlorite, biotite), absence of visible quartz grains and a higher specific gravity than rocks mapped as intermediate. Lithologies mapped as 'mafic' are believed to equate chemically with basaltic to andesitic precursors. In general, mafic metavolcanics weather a greenish black and are more greyish black to black in fresh surface. Amphibolization of the rocks is ubiquitous, producing a fine to medium, equant groundmass of amphibole (typically hornblende). This is particularly evident north of Island Lake where hornblende porphyroblasts up to 8 mm overgrow a fine-grained amphibole-plagioclase groundmass.

Mafic volcanic rocks are grouped into 1) flows, which form more than 80 percent of the unit, and 2) fragmentals, comprising less than 20 percent of the unit. Flow-type rocks (subunits 1a, 1b, 1c) are typically fine to medium grained, rarely coarse and generally possess a moderate to well-developed schistosity. The flows appear to be relatively thin (less than 5 m). Thicker flows occur north of Island Lake where the rock is increasingly coarser, and texturally resembles metagabbroic sills. Mafic rocks provided the majority of way-up determinations in the area through the occurrence of flow-top breccias ('rubble-tops'), flow-bottom breccias with rip-up clasts, as well as truncated flow surfaces and pillow flows.

Mafic pillow flows (subunit 1b), although not particularly common in the area, outcrop around a small lake east of Jojay Lake and north of Island Lake. The pillows are apparently not greatly distorted or deformed, displaying closely packed balloon- to bun-shaped structures with average dimensions of 1.0 m long by 0.5 m thick, and ranging up to 2.0 m long by 1.0 m thick. Pillow selvages, ranging from 1.0 to 5.0 cm thick, commonly overlie highly vesicular zones which may extend through to the cores of the pillows. Pillow interstices are generally composed of a very fine, cherty-looking matrix, which in places displays a crude layering with angular lapilli or smaller fragments (1 to 5 mm).

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[1] This report follows the recommendations by the Ontario Geological Survey in "Volcanic Rock Classification in Precambrian Geology Reports".

A particularly striking feldspar-phyric mafic member (subunit 1c) outcrops along the central arm of Star Lake and in several locations east of Jojay Lake. The rock is characterized by euhedral, tabular feldspar laths ranging in length from 0.5 cm to 3.0 cm, in a finer groundmass of amphibole, chlorite and biotite. Feldspar phenocrysts commonly vary in grain size from fine at the base to coarser in the centre and fine towards the top of the flow. Primary flow orientation of the phenocrysts is commonly preserved in the centre of the flows, but a more random phenocryst orientation near the margins is attributed to differential movement near the base and top of the flows.

Fragmental deposits include mafic tuff-breccias and agglomerates (subunit 1d) and mafic lapilli-tuff to ash tuff deposits (subunit 1e). Mafic fragmentals are not as widespread as intermediate pyroclastics. Mafic tuff-breccias occur between Katty Lake and Star Lake as well as about 1.5 km north of Island Lake. Fragments range from monolithic to heterolithic, are generally less mafic than the matrix and typically angular, display little or no sorting and comprise between 15 and 75 percent of the rock. A large exposure 1.5 km north of Island Lake is made up of a chaotic array of clast-supported angular fragments, ranging from 10 to 20 cm in size, as well as larger blocks. This rock grades sharply into a thick succession of coarse massive mafic flows, and is interpreted as an explosion breccia produced very close to the centre which may have produced the adjacent flows.

Mafic metatuffs ranging from lapilli to ash size (subunit 1e) occur to a limited extent along the east shore of Jojay Lake, and locally southeast of Neyrinck Lake. These rocks are typically very fine greyish black to grey and range from massive to very thickly laminated to thinly bedded units. Ash tuffs locally grade into very fine mafic-rich metasediments (i.e. pelitic schists and argillites).

Calcified and chloritized mafic volcanics (subunit 1f) are common along north-south faults extending through the Jojay-Katty-Star Lakes area. As much as 35 percent of some fault breccias have been replaced by medium- to coarse-grained euhedral white calcite. Trace amounts of euhedral pyrite (less than 2 percent) are usually present in these highly altered mafic rocks.

Mafic volcanics found close to the acid plutons are commonly migmatized, amphibolitized, granitized and epidotized, resulting in 'hybrid' amphibolitic to dioritic gneisses (subunit 1g). These rocks are particularly prevalent in the area extending between Island Lake and Fork Lakes and along the southwest margin of the Island Lake Pluton.

Intermediate Metavolcanics (Unit 2):

Metavolcanic rocks considered to be chemically equivalent to andesites and dacites make up roughly 25 percent of the supracrustal succession in the area mapped. They contain 15 to 35 percent mafic minerals (primarily chlorite and biotite with lesser amounts of amphibole), up to a few percent quartz and are generally less dense than the mafic volcanics. Colours range from medium to pale green, slate greyish green, grey, greyish brown to pale brown on both fresh and weathered surfaces.

Fragmental intermediate volcanics are noticeably more prevalent in the northern part of the map area but give way to flow-type rocks between McLennan and Star Lakes. Intermediate flows (subunit 2a) are typically fine- to medium-grained equigranular rocks possessing a poor to moderate schistosity. Primary flow textures and structures such as pillows and flow-related breccias were not observed. Amygdaloidal flow tops are believed to be represented by rocks containing ovoid to lenticular inclusions of quartz and feldspar that appear to increase in concentration across the outcrop.

Pyroclastic deposits in the north range from tuff-breccias and agglomerates (subunit 2b) to fine-grained tuffs (subunit 2c). The tuffs range from lapilli tuffs to lithic and crystal tuffs, and minor ash tuffs. In the tuff-breccias and agglomerates (subunit 2b) fragment populations are mainly heterolithic and generally more felsic than the matrix. Accessory fragments appear to be more common than essential clasts. Subunit 2b occurs in three main 'centres' along a roughly north-south trend between Jojay Lake and Star Lake. These centres of coarse pyroclastics grade along strike into finer tuffaceous material interlayered with intermediate and mafic flows. Along the southeastern shore of Jojay Lake, fine-grained intermediate pyroclastics are intimately layered with more felsic pyroclastics and metasediments. To the west and southwest of Star Lake, lapilli and lithic tuffs are increasingly intermixed with and indistinguishable from metagreywackes (psammitic to semipelitic gneisses and schists).

Porphyritic feldspar flows (subunit 2d), characterized by small (2 to 4 mm) euhedral plagioclase crystals in a dark to medium grey groundmass, are increasingly prevalent northwest of McLennan Lake. Although individual flow members in the McLennan Lake Tectonic Zone are difficult to identify due to deformation, at least 350 m of porphyritic flows may be present. Epidotization, chloritization, hematization and variable deformational fabrics characterize these rocks.

'Hybridized' migmatitic rocks (subunit 2e) of presumed intermediate volcanic precursors occur proximal to late phase felsic intrusives, and commonly merge mineralogically and texturally with 'hybridized' mafic volcanics (subunit 1g).

Felsic Metavolcanics (Unit 3):

Felsic metavolcanics make up less than 10 percent of the supracrustal rocks in the area. They are distinguished as having less than 15 percent mafic mineral content (biotite, chlorite and amphibole) and range from pale brown to pale grey, greyish white and greyish orange. The rocks are fine to very fine, siliceous to cherty and commonly display subconchoidal fracture surfaces. This unit is considered to be chemically equivalent to dacitic-rhyodacitic-rhyolitic rocks.

Felsic flow rocks (subunit 3a) outcrop at the south ends of Jojay Lake and Star Lake as well as in a few scattered exposures elsewhere. Felsic flows tend to have abrupt non-gradational contacts with adjacent volcanic lithologies. Fragmental rhyolitic or autobreccia flows (subunit 3b) occur in a series of outcrops along the old mine road between Jojay and Mallard Lakes. The rock comprises monolithic blocky and angular fragments, ranging from 2 to 40 cm in size, with little to no matrix material.

Most of the felsic metavolcanics are represented by lapilli or crystal tuff deposits (subunit 3c). These rocks vary extremely, both vertically and laterally, grading into quartz-sericite metagreywackes as well as tuffs of intermediate composition. Most outcrops comprise relatively massive to uniform material several metres or more thick. Primary structures are not prevalent; however, thinly to thickly laminated bedding and small-scale, subtly cross-laminated members, as well as fining and coarsening sequences, were occasionally recognized.

In one outcrop along the east bay of Jojay Lake the weathered surface shows flattened lozenge-shaped fragments. This rock is interpreted as a felsic agglutinate produced from a spatter-cone, under a subaerial environment. Another exposure nearby on Jojay Lake contains roughly spherical 'concretion-like' features in a fine schistose felsic matrix. In these, a very fine rind surrounds a coarser grained more weathered core. These may represent 'cannon-ball' bombs deposited in pyroclastic felsic tuffs, again indicative of a subaerial environment.

Metasedimentary Rocks (Unit 4):

Metasedimentary rocks have been divided into those within the La Ronge Domain (subunits 4a to 4h) and those comprising the McLennan Group (subunit 4i).

In the La Ronge Domain, the metasediments are considered to be derived from waterlain deposits derived in turn from more or less unlithified pyroclastics (subunits 4a, 4b, and in part 4c and 4d), with lesser amounts of sedimentary material derived from reworking of lithified rocks (subunits 4c, 4d, 4e, 4f and 4g). If a large proportion of the metasedimentary rocks were derived from unlithified volcanic material, this may explain the complex interfingering and transition which takes place between volcanic and sedimentary rocks. This tentative interpretation is based on the following observations:

1) The rocks are typically fine grained and well sorted, indicating the presence of a mature sorting mechanism.
2. There is a general absence of potassium feldspar, suggesting little contribution of material from granitoids or 'arkosic' terrain.
3) The rocks resemble or are indistinguishable from fine-grained intermediate to felsic tuffs, and are commonly interlayered with unequivocal metasediments such as calc-silicates, graphitic pelites and argillites.
4) Larger sized fragments such as volcanic blocks (greater than 64 mm) and large lapilli-sized fragments are generally absent.

These criteria are similar to those used by Muir (1982) for rocks in the Hemlo area which he considers to be "neither clearly pyroclastic nor clearly sedimentary in origin".

In several locations, the transition between sedimentary and volcanic assemblages is marked by an abundance of hematite-, pyrite- and locally graphite-bearing pelitic rocks (subunit 4e). These rocks may reflect a primary composition or postdepositional hydrothermal activity. Fairly magnetic rocks outcropping continuously for 100 m or more along the western bay of Star Lake contain very dense massive pyrite and a lesser amount of pyrrhotite in a siliceous matrix. This horizon, possibly a lean iron formation(?), occurs close to the transition between intermediate flows and metasediments.

Primary sedimentary structures and textures are not particularly well preserved in these rocks. Thinly bedded (1 to 3 cm) to extremely thickly bedded (greater than 3 m) compositional layering is easily recognizable in the Jojay Lake area and southwest of Star Lake. Primary compositional layering is strongly attenuated and transposed with increasing heterogeneous deformation in the Alpat Lake area.

Feldspathic meta-arenites (subunit 4i) of the McLennan Group outcrop along the shore of McLennan Lake and along Highway 102. The rocks are typically medium to fine grained, and display various shades of pink, red and grey on both weathered and fresh surfaces. Generally a strong tectonic fabric occurs parallel to subparallel with compositional banding; fabrics intensify westwards towards the junction with the metavolcanics where they are submylonitic to mylonitic. Sillimanite-quartz knots (faserkiesel) and coarse muscovite sheaves (retrogressive after sillimanite) occur along this tectonic foliation plane, and define a linear fabric slightly oblique to compositional layering. Some of these sillimanite and muscovite aggregates form clusters up to 8 cm in length.

Basic Intrusive Rocks (Unit 5):

A suite of slightly metamorphosed rocks ranging in composition from diorite to gabbro, and locally pyroxenite, form a number of small intrusive bodies in the area. Variants include leucogabbro (less than 30 percent mafics), mesogabbro (30 to 60 percent mafics) and melagabbros (60 to 90 percent mafics); the last-mentioned commonly grade into hornblendites. Three large intrusive bodies, the Neyrinck Lake, Fork Lake and Transom Lake Intrusions, occur in the area. The last two may be the same intrusion, as their relation is obscured by drift. Small bodies of melagabbro to hornblendite occur throughout the area, notably just northwest of Fork Lakes where narrow 'sliverlike' bodies appear to occur as large xenoliths or roof pendants(?) in later acid intrusives.

The Neyrinck Lake Intrusion in the southwest forms a northeasterly trending body approximately 6 by 2 km in size (Morris, 1961). The most northerly portion of the intrusion mapped this field season is primarily composed of medium to coarse, light grey, grey, bluish-grey, leucogabbro (subunit 5h) and mesogabbro (subunit 5i) with minor amounts of melagabbro (subunit 5j). Large porphyritic plagioclase (2-3 cm in diameter) in places display an iridescent greyish-blue colour. Original pyroxene has been mainly replaced by hornblende, chlorite and biotite. The southeastern margin of the intrusion tends to be more mafic than the centre of the body. The rock is essentially massive, although a poorly developed planar mineral orientation was observed in several localities. At one shoreline exposure towards the south end of Neyrinck Lake, preserved rhythmic layering was observed within a large trough cross-laminated structure in leucogabbro.

The Fork Lake Intrusion forms a sill-like body underlying a point at the west end of the lower part of Fork Lakes. Shoreline exposures along the west side of this point are made up of alternating outcrops of leucogabbro (subunit 5a) and melagabbro (subunit 5b). The leucogabbro contains euhedral white plagioclase (in excess of 60 percent of the rock) with interstial anhedral hornblende and minor pyroxene. The melagabbro comprises euhedral hornblende (pseudomorphs of pyroxene) with a matrix of anhedral white plagioclase. Towards the north tip of the point on Fork Lakes, coarse to very coarse pyroxenites (subunit 5c) outcrop. Layering produced by varying pyroxene mineralogy is found on a small island about 100 m farther north. Hornblendites (subunit 5e) outcrop on the most westerly shore of Fork Lakes, apparently as part of the main sill. These rocks are typically very coarse to coarse, massive, dark greenish black to black and very dense. On the east shore of this point is a small pod or plug of serpentized ultramafic rock (subunit 5d). This subunit is distinguished by an earthy brown friable-weathered surface, dark bluish-green fresh surface, and the presence of small cross-cutting veinlets composed of magnetite and fibrous asbestiform.

The contact between this basic sill and the later plutons is characterized by a 'hybrid' gabbro-diorite phase (subunit 5f) produced by feldspathization of the mafic rocks and extensive injection of granitic sheets.

The Transom Lake Intrusion is located about 2 km south of Fork Lakes and underlies a small area of less than 40 acres. The intrusion comprises a light grey to bluish-grey, coarse to extremely coarse, anorthositic-gabbro (subunit 5g). A jigsaw network of euhedral plagioclase laths, locally up to 8 cm in length, constitutes more than 85 percent of the rock. Rudimentary 'grain size layering' was seen in one exposure; elsewhere compositional interlayering with more mafic gabbroic rocks occurs on a larger scale.

Intermediate to Acid Intrusive Rocks (Units 6, 7, 8, 9)

Intrusive rocks of intermediate to felsic composition underlie approximately 40 percent of the map area, occurring in four main plutons: the Star Lake Pluton (unit 6), Gibbons Lake Pluton (unit 7), Island Lake Pluton (unit 8) and the Reef Lake Stock (unit 9). These intrusions have an early phase of leucodiorite to monzodiorite with very minor monzogabbro to gabbro, and a late phase of porphyritic to nonporphyritic granite and monzonite. Rocks of the early phase occur in the outer margin of the plutons and there is a transition to more acid material towards the cores. Although these plutons are broadly similar to one another, the proportion of the compositional phases in each body is different.

The margins of the plutons possess a moderately developed planar mineral orientation and are poorly foliated to massive towards the interior. Narrow zones of intense tectonism, marked by strongly foliated, submylonitic to mylonitic fabrics occur locally in all intrusions. These strongly foliated rocks occur in narrow shear zones (3 to 100 m wide) traceable up to a kilometre or more along strike.

Metavolcanic xenoliths occur in variable amounts in the outer margin of the plutons. Xenoliths range from isolated rounded to subrounded inclusions less than 5 cm long to agmatitic masses consisting of individual blocks larger than 1 m across. These agmatites are intepreted to be intrusion breccias and are particularly abundant along the southeast margin of the Island Lake Pluton.

The contacts between the plutons and the supracrustals include 1) sharp well-defined contacts commonly with zones of localized shearing (e.g. Star Lake Pluton), 2) zones characterized by multiple injection of granitic sheets and migmatization of the cover rocks (e.g. southwest contact of the Island Lake Pluton), 3) transitions marked by subtly increasing granitization of metavolcanics and metasediments towards the plutons (e.g. Gibbons Lake Pluton and the southeast margin of the Island Lake Pluton), and 4) large-scale complex interlayering of metavolcanic and plutonic rocks (e.g. north margin of the Island Lake Pluton).

Dykes and Sills (Unit 10)

Felsic to mafic dykes and sills are found throughout the map-area and are divided into two broad groups: 1) spatially related mafic, intermediate and felsite dykes, and 2) granitic (*sensu lato*) intrusives related to late acid plutons.

Felsite dykes (subunit 10a) and *intermediate to mafic dykes* (subunit 10b) intrude mafic to intermediate metavolcanic rocks, as well as the Star Lake Pluton and basic rocks of the Neyrinck Lake and Transom Lake Intrusions, but are absent from the Island Lake Pluton, Gibbons Lake Pluton, Fork Lakes Intrusive and the felsic metavolcanics and metasediments. The dykes average 0.5 to 1.0 m in thickness and some have been traced for several hundred metres or more, mainly in northeast-trending 'swarms' consisting of several compositional and textural varieties. The dykes in these 'swarms' display low angle cross-cutting relations with respect to one another, as well as evidence of multiple episodes of emplacement. Two predominant dyke trends are noted: one trending approximately 030° to 040° and a second, possibly slightly younger, trending about 060°. Dips vary from 50° to vertical, with subvertical attitudes most prevalent. A small number of dykes were observed striking east to southeast. Pinching and swelling of the dykes is not uncommon, and is often accompanied by development of quartz veins along irregularities between the dykes and wall rocks.

Felsite dykes (subunit 10a) vary from pink and grey to white, are generally very fine grained to cherty, and regularly possess a mylonitic fabric and associated biotite lineation. The intermediate to mafic dykes (subunit 10c) are more variable in colour (grey to brownish grey, greenish grey and green to greenish black), grain size (very fine to coarse grained) and texture (massive, foliated to intensely sheared). Although many of the dykes are highly altered and deformed, they are thought to represent varieties of diabase and lamprophyre. The main area of dyke emplacement coincides with a zone of abundant xenoliths occurring in monzonites of the Star Lake Pluton (subunit 6b). Some of the larger mafic sheets in this zone are postulated to be highly altered xenolithic slabs or roof pendants of metavolvanic rock rather than dykes.

Dykes more than 50 cm thick are commonly intensely deformed while the immediate wall rocks are commonly massive. In contrast, wall rocks adjacent to sheared dykes less than 0.5 m thick commonly exhibit progressive strain fabrics towards the dyke over distances of 5 to 10 cm and rarely up to a metre or more away.

Aplite to pegmatite dykes and sills of granitic to monzonitic composition occur in substantial amounts along the margin of the Island Lake Pluton, extending for up to 300 m away from the contact. The rocks are typically massive, pink, pinkish red or less commonly grey, and comprise irregular bodies with branching apophyses, as well as undulatory and linear sheets with well-defined wall rock contacts and localized shearing.

Intensely sheared to mylonitized granitic dykes and sills occur in metavolcanic rocks southwest of Broeder Lake. These intrusive sheets are probably related to the Island Lake Pluton and are of the same age as massive granite sheets found west of the pluton. Some of these sheared granitic sills may have been previously mapped by other workers in the area as felsic metavolcanics.

A large granitic pegmatite intruding feldspathic meta-arenites (subunit 4i) outcrops over a distance of 1.5 km on the west shore of McLennan Lake. This pegmatite is pink to pinkish red and very coarse, containing K-feldspar crystals up to 15 cm long. The rock possesses a coarsely developed microbreccia to shear foliation. Retrogressive replacement of biotite by muscovite and sericite endows the rock with a greenish waxy appearance along foliation planes.

Tectonites (Units 11, 12, 13, 14)

Intensely deformed rocks exhibiting varying degrees of internal strain underlie two roughly northeasterly-trending belts, one extending through the Alpat Lake area and the other along the west side of McLennan Lake.

The Alpat Lake Tectonic Zone is a northeasterly-trending belt underlain by bands of phyllonites (unit 11) alternating with poorly foliated to strongly schistose metasediments (subunits 4c, 4b, 4e) and minor metavolcanics (unit 3; subunits 2a, 2b, 2c). The phyllonites, mapped as 'tectonic schists' and 'tectonic slates', are typically very fine grained, displaying a semiphyllitic to phyllitic sheen on foliation planes and possessing an S-fabric which imparts to the rocks a distinctive flaggy fissility. These phyllonitic rocks commonly coincide with major north-northeast-trending lineaments, and are generally best developed along the east side of these features, coinciding with their postulated footwall. Rocks immediately west of these topographically expressed structures are noticably less foliated and, hence, probably not as deformed.

The McLennan Lake Tectonic Zone forms a northeast-trending belt underlain predominantly by cataclastic to mylonitic northwesterly-dipping to subvertical, largely metavolcanic rocks (subunits 12 and 13) that reflect various stages of inhomogeneous strain. The eastern margin coincides with the transition between the La Ronge Domain and McLennan Group and is marked by a narrow zone of protomylonitic to mylonitic rocks. Although intense deformation is exhibited on both sides of this transition, most cataclasis is confined to a belt of augen to protomylonitic metavolcanics 1.5 km wide in the La Ronge Domain. Remnants of volcanic character are locally preserved within this zone; for example, tuff-breccia and lapilli tuff beds are interlayered with porphyritic intermediate flows (subunit 2d) southwest of Broeder Lake. Primary layering in this area strikes southeast, indicating 'younging' to the northeast, in contrast to the dominant tectonic foliation of the belt which strikes northeasterly and dips steeply to the northwest.

Well-foliated quartzofeldspathic rocks possessing augened to flasered and locally protomylonitic fabrics occur approximately 100 m west of Highway 102 at Cratty Lake. These grey and pinkish-grey to pink rocks are interpreted as sheared marginal parts of the Island Lake Pluton, since they are in contact with sheared intermediate to mafic métavolcanics (subunits 12 and 13) to the east and grade into lesser deformed monzonites and granodiorites (subunit 8b) of the pluton to the west.

Amphibolitization, epidotization, chloritization and minor carbonatization have also effected most of these tectonites to some degree. Intermediate composition members commonly display small (less than 2 mm diameter) syn- to post-tectonic feldspar and/or hornblende porphyroblasts which give the rocks a 'spotted' dioritic appearance.

Structural Geology

Primary volcanic features are best preserved in the area between Jojay and Star Lakes, while original textures and structures occurring in rocks around Alpat Lake and immediately west of McLennan Lake are marked by wholesale recrystallization and/or distortion of primary textures and fabrics. Nevertheless, enough way-up criteria have survived, including flow-top breccias, rip-up clasts, cross-cutting flow relations, pillow shapes and locally developed cross-laminated bedding, to suggest 'younging' of the succession towards the west and northwest in this area. Apparent local younging of metavolcanic rocks southwest of Fork Lakes towards the northeast may be due to bedding transposition associated with the McLennan Lake Tectonic Zone. The dominant strike in the area is northeast and dips are mainly moderate to steep to the northwest, although steeply inclined surfaces commonly exhibit dip reversals to the southeast and east. Confirmation of tight isoclinal folding or, alternatively, a simple northwest inclined monoclinal structure will await further analysis of the structural data.

Most metavolcanic and metasedimentary rocks possess a schistosity which is conformable or slightly oblique to primary layering. High-angle axial planar schistosity, roughly conformable to contacts of the plutons, is developed in drag folds adjacent to the intrusions. Bedding surfaces are both conformable and sharply discordant with the pluton contacts. Plutonic rocks are generally moderately to strongly foliated along their margins and are progressively less foliated towards their cores. Strongly foliated to intensely sheared zones within the plutons are clearly later than the regional penetrative schistosity.

Moderately to well-developed mineral lineations and rodding occur in supracrustal rocks throughout the map area. Most notable is a widely developed 'down-dip' lineation which plunges moderately to steeply to the north-northwest. This lineation occurs as biotite and hornblende mineral lineations, quartz-feldspar rodding, and as rodding of primary clasts in tuff-breccias, agglomerates and lapilli tuffs. This extensional fabric is reported to be a characteristic structural feature of much of the La Ronge Domain and MacLean Lake Belt (Lewry, 1983). Other types of linear elements measured in the area include: 1) steeply plunging to near vertical, north-northwest slickensiding along northeast-trending fault scarps, 2) a moderately plunging, northwest-trending intersection lineation occurring in microbrecciated phases of the Island Lake Pluton (subunit 8d), and 3) minor fold axes related to both localized drag-folding as, for example, along pluton margins and adjacent to faults, as well as to regional folding occurring around Alpat Lake.

Tight to isoclinal folding is common in migmatitic pelitic gneisses (subunit 4h) west of Alpat Lake. These minor folds have northeast-trending axial surfaces, inclined 30° to 50° southeast to east, and fold axes plunging moderately to the south and south-southwest. Towards the south end of Alpat Lake, minor folds are quite chaotic and may be related to the emplacement of the Gibbons Lake Pluton. East of Jojay Lake and extending southwards to Island Lake, the presence of gentle to moderately open folds with northeast- to east-trending axial surfaces are postulated from the field data.

Tectonites (Units 11,12,13,14) of the Alpat Lake and McLennan Lake Tectonic Zones are characterized by inhomogeneous strain. In the Alpat Lake area, deformation occurs immediately adjacent to north-northeast-trending lineaments which are interpreted to reflect faults or narrow shear zones inclined steeply to the northwest. The most intense deformation, reflected by the development of phyllonites, appears to be best developed in the footwall of many of these structures. In the McLennan Lake Tectonic Zone strain distribution is expressed in anastomosing bands of intensely deformed rocks separating lensoid blocks of less deformed material. A large-scale tectonic 'strain shadow' appears to be present on the southwest margin of the Island Lake Pluton. Lesser deformed rocks with a moderately to well-developed schistosity occupy a wedge-shaped area abutting the pluton. This wedge of apparently lesser deformed rocks, which thins to the southwest, is bounded on either side by more intensely foliated rocks. If this is a large-scale tectonic 'strain shadow', or zone of low pressure, it holds potential for the development of dilative structures which would make this a favourable area for prospecting.

Numerous lineaments are identified throughout the map area, many of which are identified as zones of faulting or shearing. Three dominant fracture sets are recognized:

1) North- to north-northeast-trending lineaments: These can be traced for more than 3 km and are more or less restricted to the supracrustals. Exposed rock is commonly brecciated, carbonatized, chloritized and pyritized. Well-developed slickensiding present in places generally indicates a dominant vertical component of movement.

2) North-northeast- to northeast-trending lineaments: These are most readily apparent in the plutons, particularly the Star Lake Pluton. Rocks exposed in or adjacent to these structures show substantial cataclastic deformation ranging from augened to mylonitized fabrics. It is probable that this set may

be of the same age as the north- to north-northeast-trending set. The slight divergence in their trend may be due to refraction related to competency differences between the volcanics and plutons.

3) East- to southeast-trending lineaments: These less well developed structures appear to locally offset other structures and hence may be the youngest episode of faulting in the area.

Metamorphism

The mafic to intermediate volcanic rocks are largely transformed into amphibolites and biotite-amphibole-rich rocks respectively. Psammitic, semipelitic and pelitic metasediments in the La Ronge Domain contain biotite, chlorite and muscovite, as well as local garnet, andalusite and staurolite. Late hornblende and chloritoid porphyroblasts occur in mafic to intermediate volcanic rocks in the northeast part of the area. Migmatization and post-tectonic growth of coarse muscovite is found in pelitic gneisses west of Alpat Lake. Quartz-sillimanite faserkiesel and associated muscovite or sillimanite folia are well developed in feldspathic meta-arenites of the McLennan Group.

Metamorphic data from the map-area indicate attainment of lower amphibolite facies conditions throughout the area west of McLennan Lake. The appearance of sillimanite in feldspathic meta-arenites of the McLennan Group indicates that middle amphibolite facies conditions were reached along the easternmost part of the area. Migmatization in pelitic rocks west of Alpat Lake may indicate an increase in metamorphic grades to the west of the map area.

Economic Geology

With the recent resurgence of gold exploration in the La Ronge district, the Star Lake area has come under more attention. Impressive results are being obtained on the Star Lake joint venture between Starrex Mining Corporation Limited and Saskatchewan Mining Development Corporation. Other gold-focused exploration programs in the area include a revived interest in the Mallard Lake-Jolu property (Decade mine) by Mahogany Mineral Resources Inc., and evaluation of several mineral dispositions by SMDC (notably MPP 1112 and CBS 8909).

In addition to gold mineralization, several occurrences of disseminated pyrrhotite and chalcopyrite-pyrrhotite are present within the area; notably at Neyrinck Lake and west of Alpat Lake. Trace amounts of pyrite and occasional pyrrhotite are found in most rock types. Small amounts of chalcopyrite-molybdenite were detected in leucogabbros of the Fork Lake Intrusion.

Star Lake Joint Venture:

The property is centred approximately 0.5 km east of the north end of the most easterly bay on Star Lake. This is an equally shared joint venture between the Starrex Mining Corporation Ltd. and SMDC (operator). Three main zones of quartz vein-type gold mineralization occur on the property: the Rush Lake zone, 21 zone and Kahn No. 18 zone. All three zones lie in the Star Lake Pluton along northeast-trending shear structures.

a) Rush Lake Zone (also known as the Pie claims): This zone is situated approximately 1 km northeast of Star Lake. Since 1945, exploratory work has been performed by several companies and individuals. The mineralization occurs in massive white to grey quartz veins emplaced along a N 050° E trending shear. The shear can be traced up to 3 km along strike and tends to be less than 3 m wide. The underlying rock type in this area is predominantly diorites of the Star Lake Pluton.

The main area of mineralization is a 1 to 3 m wide quartz vein, roughly conformable with the shear zone which dips steeply to the southeast. Metallic minerals present include pyrite, chalcopyrite and visible gold. Gold tends to display a sympathetic relation with chlorite-rich seams in the vein. There appears to be an inverse relationship between the amount of visible gold and pyrite.

Past work on the property has estimated that the main vein contains 5763 t grading 13.03 g/t Au (0.38 oz./ton Au), confined to a zone 60.9 m along strike, 1.2 metres wide and 30.5 metres down dip.

b) '21 Zone': The 21 Zone subcrops under a northeasterly-trending muskeg which drains into the northeast end of David Lake. The mineralization is confined to a dilative zone in a steeply northwest-dipping shear trending N 050° E. The mineralized structure is developed in monzonites (subunit 6b) of the pluton. A large number of mafic to felsic dykes occur in this area and are broadly conformable to the shear zone. Dykes and plutonic rocks which envelop the 21 zone mineralization range from moderately foliated, cataclastic and protomylonitic to mylonitic. The mineralized zone itself comprises relatively massive undeformed quartz with associated euhedral pyrite.

By May 1984 drilling had outlined a mineralized area with a strike length of 80 m, depth of 130 m, and a moderate to steep plunge of 55° to the southwest. Preliminary drill-indicated calculations reveal reserves of approximately 209,300 t at 17.14 g/t Au (0.5 oz./ton) with a 3.43 g/t Au (0.10 oz./ton) cut-off (SMDC news release, July 16, 1984).

c) Kahn No. 18 Vein: The Kahn No. 18 vein occurs northwest of Fork Lakes and east of David Lake. The Kahn No. 18 is a gold-bearing quartz vein infilling a northeast-trending shear fracture in monzonites of the Star Lake Pluton and is spatially associated with sheared mafic to felsic dykes. The Kahn No. 18 lies less than 200 m to the south of the 21 zone.

In contrast to the 21 zone which is characterized by late passive in-filling by massive quartz in a dilation zone, the Kahn-style mineralization is characterized by sheared ('ribbon') quartz. Sulphides in the vein are typically milled, rotated or attenuated and wall rocks to the vein are epidotized and hematitized. Gold distribution is quite erratic in the veins; however, there is a tendency for greatest concentration towards the footwall side of the vein.

The Kahn No. 18 has a strike length of 250 m along which drilling in 1981 reportedly intersected 41.8 g/t Au (1.22 oz./ton Au) over 0.5 m (SMDC news release; July 16, 1984).

Mallard Lake - Jolu Property:

The property is located between Jojay Lake and Rush Lake. Between 1946 to 1973, 44 holes, totalling about 2312 m, were drilled on the property by various groups in order to evaluate auriferous quartz veins in metasediments occurring along the contact of the Star Lake Pluton. Between 1973 to 1975, a small mining and milling operation was established by Decade Development Ltd., during which time approximately 4550 t is believed to have been milled with a millhead around 10.3 g/t Au (0.30 oz./ton Au).

The main gold-bearing zone that was mined occupies a N 045° E trending fracture system in which a series of closely spaced anastomosing quartz veins have been emplaced. The zone is from 1 to 10 m wide and can be traced for approximately 335 m. Metallic minerals present in the mineralized quartz vein include pyrite, pyrrhotite, chalcopyrite and gold, in order of abundance. Country rocks adjacent to the veins are hydrothermally altered, as indicated by coarse masses of tourmaline, chlorite, biotite and amphibole. Visible gold appears to be best developed close to the wallrocks to the vein, particularly adjacent to zones of intense tourmalinization and chloritization.

Recent results given by Mahogany Mineral Resources Inc. (news release, Aug. 20, 1984) confirmed and added to earlier estimations by outlining a zone grading 21.34 g/t (0.62 oz./ton) Au over a width of 3.4 m and a length of 91.5 m. Grab samples obtained from the newly discovered Rod showing contain coarse gold associated with pyrite. This new showing is situated about 500 m south of Mallard Lake and occurs in a northeast-trending massive quartz vein hosted by the dioritic phase of the Star Lake Pluton.

Tamar Showing:

The Tamar Showing is located about 1 km northeast of the lower arm of Fork Lakes, straddling the contact between metavolcanics and diorites of the Star Lake Pluton. Mineralization is confined to pyritized quartz within a northeast-trending shear between 4.5 and 24 m wide and extending for at least 400 m. Coombe (1975) reported that a composite chip sample from this zone assayed 2.7 g/t Au and 0.7 g/t Ag over 0.9 m.

Neyrinck Lake Cu-Ni Occurrence:

Finely disseminated chalcopyrite, pyrrhotite and local magnetite are found throughout gabbroic rocks in the Neyrinck Lake Intrusion. The sulphides appear to be most prevalent in the leucogabbroic phases of the intrusion and locally form narrow veinlets or blebs up to a centimetre in diameter. One zone of reported Cu-Ni enrichment occurring along the west boundary of the map sheet east of Neyrinck Lake has a reported strike length of 137 m and widths ranging from 9 to 31 m. Five holes totalling 664 m drilled below this steep southwesterly-dipping zone intersected mineralization. Assays were considered low: 0.2 to 0.3 percent Cu and 0.05 percent Ni, while a 1.5 m section returned 18.5 g/t Ag (Assessment Files 73P16-NW-0012, 0020, 0021, Saskatchewan Energy and Mines, Regina).

Alpat Lake Ni Occurrences:

Disseminated pyrrhotite occurs in amounts up to several percent in metasedimentary rocks west of Alpat Lake. Pyrrhotite enrichment was reported by Morris (1961) at the south end of a narrow, north-south oriented lake, about 1.5 km west of Alpat Lake.

Selected Bibliography

Bickford, M.E., Lewry, J.F. and Van Schmus, W.R. (1983): Zircon isotope geochronology project: U-Pb (zircon) chronology for the Hudsonian Orogenic Terrains in Saskatchewan; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p34-39.

Budding, A.J. (1955): The geology of the Settee Lake area (east half); Sask. Dep. Miner. Resour., Rep. 17.

Gracie, A.J. (1967): The geology of the Maribelli Lake area (west half), Saskatchewan; Sask. Dep. Miner. Resour., Rep. 113.

Higgins, M.W. (1971): Cataclastic rocks; U.S. Geol. Surv., Prof. Pap. 687.

Lewry, J.F. (1983): Character and structural relations of the McLennan Group meta-arkoses, McLennan-Jaysmith Lakes area; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p49-55.

Lewry, J.F., Abraham, A. and Wilson, G.B. (1980): La Ronge project; in Summary of Investigations 1980, Sask. Geol. Surv., Misc. Rep. 80-4, p23-28.

Macdonald, R. and Broughton, P. (1980): Geological map of Saskatchewan, provisional edition; Sask. Miner. Resour., scale 1:1,000,000.

McLarty, D.M.E. (1935): Lac La Ronge sheet (east half), Saskatchewan; Geol. Surv. Can., Map 358A, scale 1:253,440.

McMurchy, R.C. (1938): Foster Lake sheet (east half), north Saskatchewan; Geol. Surv. Can., Map 433A; scale 1:253,440.

Miller, M.L. (1949): The geology of the Windrum Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 3.

Morris, A. (1961): The geology of the Settee Lake area (west half), Saskatchewan; Sask. Dep. Miner. Resour., Rep. 55.

Muir, T.L. (1982): Geology of the Hemlo area, District of Thunder Bay; Ont. Geol. Surv., Rep. 217.

Spry, A. (1969): Metamorphic Textures; Pergamon Press, 350p.

Tella, S. and Heywood, W.W. (1978): The structural history of the Amer. Mylonite Zone, Churchill Structural Province, District of Keewatin; in Current Research, Part C; Geol. Surv. Can., Pap. 78-1C, p79-88.

Watters, B.R. (1981): Geochemistry of metavolcanic rocks in the La Ronge Domain; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p34-37.

Zeck, H.P. (1974): Cataclasites, hemiclastites, homoclastites, blastoclastites and mylobastites-cataclastic rocks; Am. J. Sc., v274, p1064-1073.

COMPILATION BEDROCK GEOLOGY

Project 8406

Bedrock Compilation, Lac la Ronge and Wapawekka Areas (NTS 73P/73I)

by J.F. Lewry[1]

Lewry, J.F. (1984): Bedrock compilation, Lac la Ronge and Wapawekka areas (NTS 73P/73I); *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The accompanying geological compilation map and legend are based primarily on an office preliminary in-file edition by R. Macdonald, W.L. Slimmon and the author in April, 1984, with amendments deriving from this summer's field investigations and, in some cases, from the author's interpretive biases. Reference was also made to an earlier unpublished compilation map prepared by L.H. Forsythe in 1978. The contributions made by others are gratefully acknowledged; however, any changes from previously published maps of the area are entirely the author's responsibility.

The Lac la Ronge map area encompasses parts of four previously defined lithotectonic domains of the Early Proterozoic 'Trans-Hudson Orogen' (Hoffman, 1981; Lewry et al., in press) within northern Saskatchewan. This summary utilizes further provisional and informal subdivision of some domains, based on differences in structural and/or lithological character (Fig. 1).

Wollaston Domain

This domain comprises varied high metamorphic grade granitoid and granitic (sensu lato) gneisses, and minor metagabbro/metadiorite, which form a continental basement, of probable Archean age, to unconformably overlying tightly infolded Early Proterozoic supracrustal rocks of the Wollaston Group. The latter include mature platformal-miogeoclinal quartz-pebble conglomerates, orthoquartzites, feldspathic quartzites, muscovite schists (aluminous pelites), calc-silicates and pelitic to psammopelitic schists and gneisses, overlain by meta-arkoses which probably also form part of a passive margin sequence. Locally, the lowermost quartzitic units of this succession are themselves underlain by immature meta-arkosic psammites and conglomerates of possible rifted continental margin affinities. In the Needle Falls area, these form a thin, basal, continental to fluviatile sequence passing gradationally into conformably overlying quartzites and quartz-pebble metaconglomerates. Contacts between Archean basement and the Aphebian cover are highly strained, with consequent obscuring of primary relationships and possible tectonic elimination of parts of the cover succession. Some biotitic supracrustal rocks in the domain may represent Archean metasedimentary remnants.

The reader is referred to Lewry and Sibbald (1980) and literature cited therein for more detailed description of character and evolution of the Wollaston Domain.

Rottenstone Domain

As elsewhere in the domain (cf. Lewry et al., 1981), two main lithological subdivisions are recognized: a) the Wathaman Batholith and associated plutons and b) the Tonalite-Migmatite Complex.

The Wathaman Batholith and Comagmatic Plutons:

The western part of the domain mainly comprises plutonic rocks regarded as approximately coeval, comagmatic components of the Wathaman Batholith, and forms the most southerly exposed part of this huge pluton (Lewry et al., 1981; Fumerton et al., in press). Included are most rocks previously designated by Money (1965), Morris (1963, 1965) and Forsythe (1971a, b, 1972) as porphyritic (or porphyroblastic) and non-porphyritic, intensely flasered to massive granite, quartz monzonite and granodiorite, and 'augen gneisses'. The batholith is generally more heterogeneous, and the eastern boundary more complex and less clearly demarcated in the Lac la Ronge area than to the north. It includes the coarsely megacrystic quartz monzonite/monzogranite typical of the main phase core to the north, as well as extensive areas of poorly megacrystic to non-megacrystic pink to grey equigranular granite and granodiorite, which are irregularly distributed and exhibit complex and locally gradational contacts. Much of the batholith is highly xenolithic and migmatitic, with extensive screens (roof pendants?) and xenolithic trains of country

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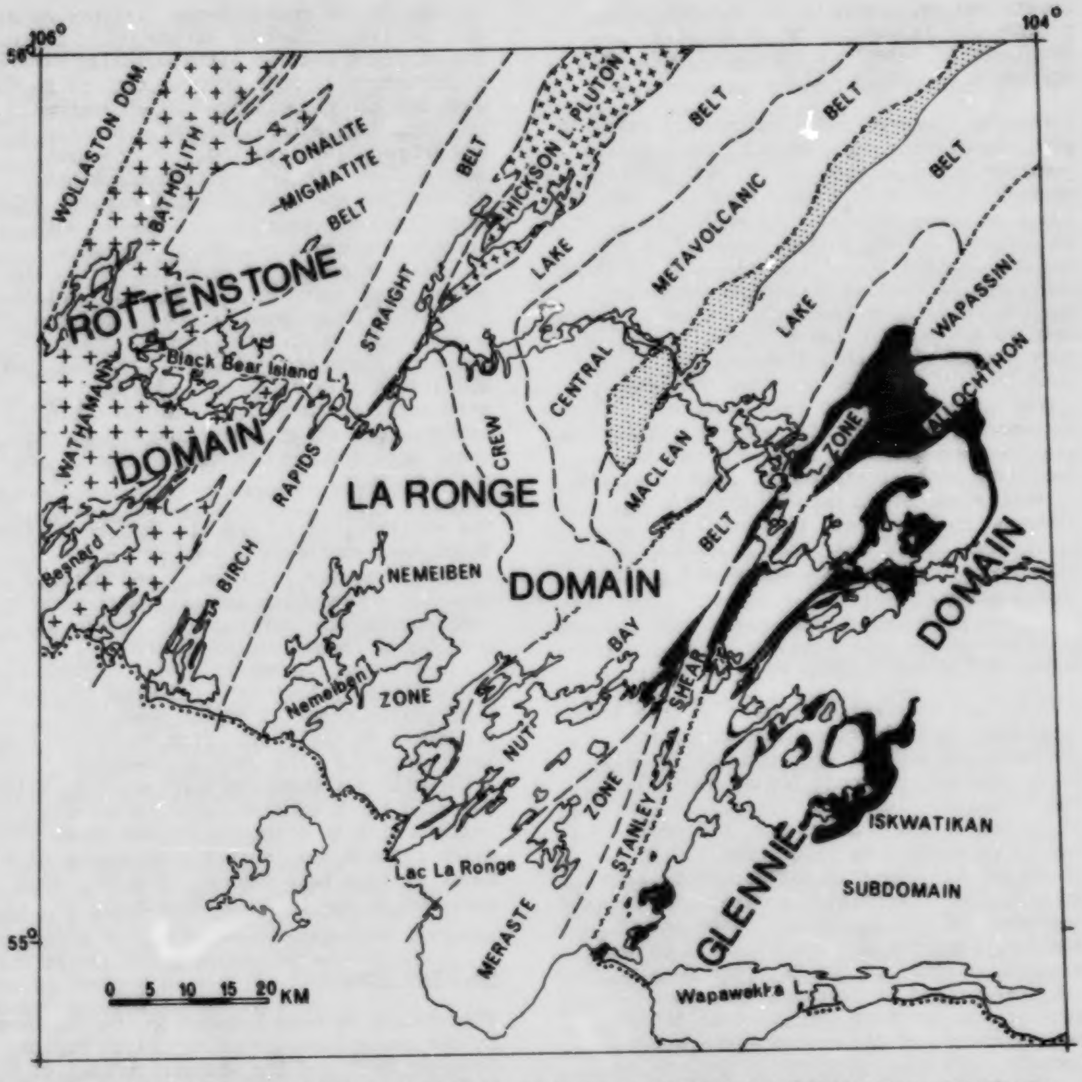
106°
104°
56°
55°
WOLLASTON DOM.
WATHAMAN BATHOLITH
TONALITE
MIGMATITE
BELT
ROTTENSTONE
DOMAIN
Black Bear Island L.
Besnard L.
BIRCH
RAPIDS
STRAIGHT
BELT
HICKSON L. PLUTON
LAKE
BELT
CENTRAL
METAVOLCANIC
BELT
LAKE
BELT
WAPASSINI
ALLOCHTHON
ZONE
CREW
MACLEAN
BELT
LA RONGE
DOMAIN
NEMEIBEN
Nemeiben L.
ZONE
NUT
BAY
SHEAR
STANLEY
ZONE
MERASTE
Lac La Ronge
DOMAIN
GLENNIE
ISKWATIKAN
SUBDOMAIN
Wapawekka L.
0 5 10 15 20 KM

Figure 1 - Major lithostructural elements of the Lac la Ronge area. Explanation of symbols: stipple - McLennan Group meta-arkoses; black - areas mostly underlain by intensely strained, submylonitic to mylonitic rocks of the Guncoat and Nistowiak Gneisses.

rock, mostly comprising hornblende gneisses and amphibolites. These are typically associated with heterogeneous inequigranular to pegmatitic granite phases. The eastern boundary of the batholith is extremely irregular. Major intrusive tongues extend northeastwards, and disconnected satellitic bodies and extensive areas of metasomatized older country rocks occur within a complex metasomatic aureole.

Most rocks included in the Wathaman Batholith are weakly to only moderately flasered. More intensely deformed variants are mainly restricted to the western part of the batholith in the vicinity of the Needle Falls Shear Zone, which defines the junction between the batholith and the Wollaston Domain. Over an interval of several hundred metres in this zone, there is westward transition from weakly to moderately foliated rocks into increasingly strongly flasered and comminuted augen gneisses and then into laminated mylonitic gneisses of the shear zone proper. Regular compositional banding in the latter partly derives from extreme tectonic attenuation and transposition of various components of the Wathaman Batholith, including the main phase megacrystic monzogranite, later aplitic and pegmatitic sheets and mafic xenolithic screens; this progressive transposition is clearly displayed in lakeshore exposures east and northeast of Needle Falls.

Intensely flasered and subsequently refolded pink megacrystic and augened monzogranitic gneisses occur around central and northern parts of Black Bear Island Lake (cf. Morris, 1965) in close proximity to weakly foliated porphyritic monzogranites assigned to the Wathaman Batholith. These flasered rocks may represent an earlier Hudsonian intrusive episode or Archean basement. However, around Besnard and Morning Lakes (Forsythe, 1971a) very similar intensely flasered and ubiquitously refolded granitic gneisses appear transitional to less deformed Wathaman-type porphyritic and non-porphyritic granites and granodiorites, and may mark localized high strain zones. Age relations in both areas are presently unresolved, although the intensely flasered rocks on Black Bear Island Lake have been sampled for U-Pb zircon dating (Van Schmus and Bickford, this volume).

Tonalite-Migmatite Complex:

Most of the Rottenstone Domain in this area comprises variably migmatized supracrustal gneisses and subordinate, compositionally heterogeneous, plutonic bodies equivalent to the 'Tonalite-Migmatite Complex' of Lewry et al. (1981). The supracrustal paleosome is mostly metagreywacke-type psammitic to psammopelitic biotitic metasediments with subordinate intercalated pelites, hornblendic gneisses and amphibolites. These are of similar character and transitional to less migmatized rocks of the La Ronge Domain; they are interpreted as volcanogenic, possibly arc-derived clastics and volcaniclastics. Meta-arkosic and calcareous rocks occur locally. Neosomal components include an early, pre- or syn-kinematic suite of strongly foliated and folded quartz dioritic-tonalitic-trondhjemitic-granodioritic gneisses, less deformed to unfoliated rocks of a similar compositional range, and a later synkinematic suite of pink leucogranites, pegmatites, megacrystic and nonmegacrystic monzogranites which, at least in part, may be coeval with the Wathaman Batholith. The plutonic rocks form both major elongate intrusive bodies and neosome in the migmatitic gneisses.

The eastern part of the Tonalite-Migmatite Complex is separately defined, on structural grounds, as the Birch Rapids Straight Belt. This belt is distinguished by markedly linear and regular northeasterly structural and aeromagnetic trends, and is traceable southwards for considerable distance as a distinctive subsurface aeromagnetic feature. The straight belt is lithologically similar to structurally more complex regions to the west but is characterized by an intense regular, high strain, planar kinematic fabric and subparallel layering. In the section betwen Clam Lake and eastern Black Bear Island Lake the belt mainly comprises mildly migmatized greywacke metasediments with minor hornblendic gneisses, early intensely foliated to mylonitic granitic gneiss sheets, and a later suite of less strongly foliated but highly boudinaged leucogranites and pegmatites. Restricted protomylonite-mylonite zones occur locally but most rocks are less highly strained. Observed structural features indicate that both extreme pure shear flattening and simple shear were involved in development of the straight belt.

The eastern part of the straight belt, from Trout Lake southwards, includes a zone of varied intensely flasered to mylonitized pink granitic rocks which include 'Wathaman-type' pink megacrystic monzogranite previously designated 'augen gneisses' and 'meta-arkoses' by Morris (1963). These pass transitionally into less deformed to massive porphyritic granites of the Nemeiben subdomain to the east. From MacIntosh Lake northeastwards, the straight belt is apparently intruded and supplanted by mildly deformed to undeformed, pink, generally uniform biotite granodiorite and pegmatite which represent a southerly extension of the major Hickson Lake Pluton. The latter is included in the La Ronge Domain.

La Ronge Domain

This domain is here bounded on the northwest by the eastern margin of the Birch Rapids Straight Belt and the western contact of the Hickson Lake Pluton, and on the southeast by the late-tectonic Stanley Fault. Six subdomains are here informally defined:

The Crew Lake belt is characterized by predominantly biotitic, medium- to fine-grained supracrustal rocks, generally categorized as 'biotite granulites, gneisses and migmatites' by previous workers, with subordinate intercalated hornblendic gneisses and amphibolites. Previous descriptions, and the present author's observations in the southern part of the zone, suggest that they were largely derived from psammitic to pelitic metagreywackes and other volcanogenic metasediments. However, investigations by Macdonald (this volume) in the LaRoque-Forbes Lakes area indicate that at least part of the succession may be derived from volcanics and volcaniclastics.

The Central Metavolcanic belt includes predominant tholeiitic to calc-alkaline basic to subordinate felsic metavolcanic rocks, proximal volcaniclastics and epiclastics, as well as subordinate interlayered volcanogenic metasediments. These are intruded by elongate to ovoid plutons ranging compositionally from granitic to ultramafic. Field, petrographic and geochemical data support its interpretation as a remnant of an island arc, probably subduction related. Geochronological data (Van Schmus and Bickford, this volume) indicate that the arc is of Early Proterozoic age.

The metavolcanic belt is generally of low metamorphic grade and is relatively weakly deformed, compared to adjacent parts of the La Ronge Domain. Although characterized by ubiquitous pervasive foliation, primary volcanic and sedimentary microstructures and textures are widely preserved (e.g. Harper, D.J. Thomas, this volume), save in localized high strain belts such as the McLennan Lake Tectonic Zone (previously termed the McLennan Lake 'Thrust' by Lewry, 1983), which defines the southeastern boundary of the belt. Major fold closures have not been identified, and mapping by D.J. Thomas (this volume) suggests that the metavolcanics may form a relatively simple northwesterly dipping homoclinal package.

It is speculated that the Central Metavolcanic belt may be allochthonous, forming a structurally high-level and internally little deformed competent tectonic slice structurally overlying the McLennan Lake Tectonic Zone and the intensely deformed forearc assemblage of the MacLean Lake belt.

Plutons in the Crew Lake and Central Metavolcanic belts are generally composite, compositionally heterogeneous bodies. Both individual plutons and components within them may vary considerably in age (D.J. Thomas, this volume; Van Schmus and Bickford, this volume). Typically, there is passage from an outer mafic quartz diorite/granodiorite zone into quartz monzonite and granite in the cores. Most appear to be massive or only moderately foliated, save locally in restricted internal high strain zones and near the margins of the belt.

The MacLean Lake belt includes two contrasting lithological assemblages:

1) Meta-arkoses, granitoid meta-arkoses and probably derivative granitic and pegmatitic neosome of the McLennan Group, which form a continuous belt in the northwestern part of the subdomain (Abraham and Lewry, 1981; Lewry, 1983; Nighswander and Lewry, this volume) and are considered lateral equivalents of the Sickle Group in Manitoba.

2) A mixed assemblage of psammitic to psammopelitic metagreywackes, pebbly metagreywackes, polymictic metaconglomerates, and varied hornblendic to amphibolitic gneisses interpreted as tuffaceous sediments, volcaniclastics and minor volcanics, which lie southeast of the McLennan Group. This assemblage has been tentatively interpreted as a telescoped forearc basin suite (Lewry, 1981a).

The "granites or arkoses" (unit 9 of Forsythe, 1968, 1971b) northeast of Hebden Lake are in fact meta-arkoses and arkosic metaconglomerates. Limited field observation, airphoto and aeromagnetic data indicate that they extend for a considerable distance northeastwards into the Stanley map area (Mawdsley and Grout, 1951) within a complex fold core. Although not in continuity with the main belt of the McLennan Group, they are very similar in character and are tentatively correlated with the latter.

The zone from Hebden Lake northwards through MacKay Lake to the Haugen Lake synform closure includes abundant metaconglomerates of variable character (Forsythe, 1968, 1971b). Most are polymictic, with a rather mafic, greywacke-type or hornblende-bearing matrix, similar to those in the Otter Lake area. Other metaconglomerates, including those adjacent to the Hebden Lake meta-arkoses discussed above, have a more arkosic matrix with predominant quartz and pink granitoid clasts. In the Mackay Lake area, polymictic conglomerates containing metavolcanic clasts are intruded by pink quartz-feldspar porphyry sheets (unit 8 of Forsythe, 1968, 1971b). Locally, however, more arkosic conglomerate horizons contain dominant pink granitoid clasts apparently derived from the porphyries. Spatially associated pink felsic rocks are similar in appearance to the porphyries but show evidence of clastic origin. It seems that the quartz porphyry sheets were very high level intrusions subject to penecontemporaneous exposure and erosion; they may be of economic interest.

The Maclean Lake belt, in contrast to the Central Metavolcanic belt, is intensely strained. At least two foliation and isoclinal fold forming events, accompanied by localized high strain zones along fold limbs, are involved in producing the dominant northeasterly structural grain. A pervasive 'downdip' lineation is characteristic. The subdomain comprises a series of fold/thrust packages and is thought to have undergone extreme crustal shortening.

The Nemeiben zone, forming the southwestern part of the La Ronge Domain, consists predominantly of 'early' prominently foliated and refolded metaplutonic rocks, mostly biotite-bearing granodiorites to granites, with subordinate intercalated supracrustal rocks. The early foliated metaplutons and subparallel supracrustal strips are complexly refolded on a megascopic scale, but overall is broadly arcuate trending, from northeasterly in the northwest to more easterly to southeasterly in the southeast. Junctions with adjacent subdomains are arbitrary and transitional.

The Nut Bay belt, characterized by strongly linear to gently curving structural trends, extends southwestwards to the northwestern part of Lac la Ronge, where it appears to pass transitionally into the structurally more complex Nemeiben Lake zone. Unlike the MacLean Lake subdomain, this belt comprises dominant elongate zones of relatively homogeneous, strongly foliated biotitic and/or hornblendic granitic rocks intercalated with subordinate supracrustals. The latter are mainly hornblende gneisses and amphibolites of probable metavolcanic or metavolcaniclastic derivation, with subordinate biotitic metasediments. Mafic to ultramafic plutonic rocks occur locally. In places, as for example around Lynx, Sulphide and Hunt Lakes, and Waden Bay, fine-grained intensely foliated and locally laminated amphibolites ('mafic mylonites') previously interpreted as metavolcanics are demonstrably derived from the plutonic rocks by intense heterogeneous strain. Such mafic tectonic schists may be more extensive in the Lac la Ronge area amongst fine grained mafic rocks previously interpreted as volcanogenic.

The Meraste zone extends through the central part of Lac la Ronge, wedging out to the north against the western margin of the Stanley Shear Zone. Lithologically, it differs from the Nut Bay belt in consisting mainly of more mafic and generally richly hornblendic quartz diorite and granodiorite gneisses with abundant zones of amphibolite and amphibolite migmatite, more akin to rocks within the Stanley Zone. This is reflected in a distinctive aeromagnetic signature, on which basis the subdomain can be clearly distinguished for a considerable distance beneath Phanerozoic cover to the south. To the east, the subdomain is gradational into the Stanley Shear Zone (Lewry, 1981b), with increasing general intensity of planar fabrics and incidence of protomylonitic and mylonitic gneiss zones. Local zones of intensely sheared fine-grained to mylonitic gneisses, including many of the rocks previously included in Units 7, 9 and 10 by Forsythe (1981) were identified near the northwestern margin, but no continuous well-defined shear zone is evident.

Glennie Domain

As discussed elsewhere (eg. Lewry, 1981b), the Glennie Domain forms a clearly defined lithostructural entity. As compared to the La Ronge Domain, it is distinguished by complex, arcuate to closed structural trends developed by large amplitude Type 1 and Type 2 interference of northerly (D_3) and northeasterly (D_4) trending major folds which deform earlier flat-lying foliation and coeval isoclines of two generations (D_1 and D_2). In much of the domain the late interference structures are relatively open and regional foliation is predominantly flat-lying to gently dipping, in contrast to that in most of the La Ronge Domain. This change from a steep northwesterly dipping structural style to shallower arcuate trends approximately coincides with the Stanley Shear Zone in the southwest. Northeast of Guncoat Bay, however, there is transitional continuity between steeply dipping structures of the MacLean Lake and Nut Bay belts and flat-lying refolded foliation and early folds of the Glennie Domain; here, the northeasterly continuation of the late brittle Stanley Fault system is arbitrarily chosen as the boundary between the two domains.

In the Lac la Ronge area, two main subdivisions of the domain are distinguished; the Iskwatikan subdomain and the Wapassini Allochthon:

The Iskwatikan subdomain, lying in the south, structurally underlies tectonic schists and mylonitic rocks of the 'Guncoat Gneisses' (Lewry, 1981b), which are refolded around the Knight Lake Antiform - Drinking Falls synform pair. The subdomain mostly comprises highly variable and commonly migmatitic, well-foliated gneisses. These include hornblende and/or biotite quartz dioritic, tonalitic, granodioritic and granitic orthogneisses with hornblende gneiss, and fine- to coarse-grained amphibolite paleosomal remnants ranging from isolated schlieren to major semicontinuous migmatitic zones. They are commonly injected by minor to abundant biotite-bearing grey to pink megacrystic monzonite and granite, equigranular leucogranite and pegmatite, possibly of several ages. These later neosomal rock types also occur as major, relatively uniform bodies throughout the subdomain and range from massive to intensely foliated and augened.

Remapping this summer in the region of Nistowiak, Iskwatikan, Drinking, Keg and Nunn Lakes, Hunter Bay and the east side of Lac la Ronge, together with previous work (Lewry, 1981b), show that most of the rocks previously interpreted as, or implied to be, metasedimentary supracrustals (unit 4 of Mawdsley and Grout, 1951; much of units 7 and 9, of Forsythe, 1981) in the Iskwatikan subdomain are in fact highly strained submylonitic to mylonitic gneisses derived from varied metaplutonic and migmatitic protoliths. These protoliths include mafic to mesocratic quartz diorite-tonalite-granodiorite, mesocratic to leucocratic pink megacrystic and nonmegacrystic monzogranite, leucogranite and pegmatite, and, locally, heterogeneous migmatites comprising psammitic to pelitic paleosome, a plagioclase porphyroblastic tonalite neosome and more equigranular leucogranite. All of these protoliths can locally be shown to pass transitionally into 'packages' of intensely foliated to mylonitic 'beaded', augened and banded/laminated gneisses which are together here termed the 'Nistowiak Gneisses'. Some, apparently derived from migmatites with coarsely porphyroblastic neosome, are similar in character and probable derivation to the Guncoat Gneisses of the Stanley Zone. Most, however, are considered to have entirely plutonic protoliths, both megacrystic and equigranular, and overall the proportion of supracrustals in the Nistowiak Gneisses is probably less than 10 percent.

Included in the Nistowiak Gneisses are discontinuous zones of hornblende gneiss and mafic to ultramafic gneiss migmatites. The neosomes generally comprise intensely foliated to mylonitic, finely beaded to augened orthogneisses similar in character to the remainder of the Nistowiak Gneisses. Paleosomal components include fine- to medium-grained, uniform to banded hornblende gneisses and a variety of fine- to coarse-grained, massive to foliated metadiorites, leucogabbros, melagabbros and ultramafic amphibolites, which form irregular lensoid and rolled ovoid blocks and inclusions ranging in size from a few centimetres to tens of metres. A variety of paleosomal rock types commonly occurs within the same zone, in addition to lensoid 'tectonic fish' representing less deformed remnants of neosomal rock types. Some inclusions may derive from metavolcanic protoliths, but a high proportion, probably including the coarse ultramafic blocks, evidently represent a disrupted basic to ultramafic plutonic suite. These may be early xenoliths predating the neosomal gneisses or fragmented later intrusive sheets.

The intense to mylonitic planar fabric and extremely appressed, coeval isoclinal folds characterizing the Nistowiak Gneisses are considered to represent formerly flat-lying high-strain zones similar in tectonic character and significance to the Guncoat Gneisses of the Stanley Shear Zone. They are interpreted as major movement zones which formed a sole to one or more laterally transported allochthonous slices, or crustal packages, which together make up this part of the Glennie Domain. Presently unresolved structural complexities make it uncertain whether they represent one or more distinct structural levels. These planar fabrics and coeval isoclinal folds are refolded by regional north-trending (D_3) and northeast-trending (D_4) folds.

Undoubted metasediments and metavolcanics form a major east-trending belt in the southern part of the zone, in the vicinity of Wapawekka Lake (Padgham, 1966, 1967). Aeromagnetic data indicate that in the west this belt swings into a southwesterly trend beneath Phanerozoic cover and converges with the Stanley Shear Zone.

The Wapassini allochthon forms the northern, higher level part of the Glennie Domain, structurally overlying and including the refolded portions of the Guncoat Gneisses east of the Stanley Zone. It comprises a major tectonic package incorporating highly appressed, complexly refolded isoclines and formerly flat-lying foliation, probably involving at least two foliation and isoclinal fold-forming phases, which is continuous with and roots into the more steeply dipping MacLean Lake and Nut Bay belts. The allochthon includes a mixed assemblage of psammitic to pelitic greywackes, minor polymictic metaconglomerates, layered to homogeneous metavolcanics, volcaniclastics and calc-silicates similar to those characterizing the MacLean Lake subdomain. Minor metagabbroic to ultramafic bodies occur locally in this sequence. Subordinate quartz dioritic to granitic orthogneisses closely resembling those in the Nut Bay belt occur as intervening sheets, but are generally somewhat more homogeneous than in the Iskwatikan subdomain. The Guncoat Gneisses are considered to be the main component of an early kinematic, refolded high-strain zone comprising mylonitized rocks and tectonic schists derived from migmatites and later remetamorphosed at high grade. They mark the main sole, or lower detachment zone, of the Wapassini allochthonous package.

General Comments

Both previous work and this summer's observations suggest that a significant proportion of rocks previously interpreted as, or implied to be, metasedimentary and metavolcanic supracrustals in the Lac la Ronge area are in fact highly strained to blastomylonitic derivatives of various formerly coarse-grained plutonic rocks, or of migmatites with only a small proportion of supracrustal paleosome. Correct identification of such rocks is important, not only in elucidation of structural/ stratigraphic relations and tectonic history but also from the economic mineralization viewpoint. Recognition of high-strain zones, documentation of varying intensity of strain as indicated by fabric variation, and the need to distinguish between strongly foliated fine-grained metavolcanics/metasediments and intensely strained derivatives of plutonic protoliths may all be relevant to mineral exploration strategies. Gold mineralization at the Starrex property in the Central Metavolcanic belt appears to be specifically related to restricted high-strain shear zones. Many fine-grained rocks in the economically important Anglo Rouyn - Lynx Lake - Sulphide Lake belt are sheared mafic/ultramafic plutonics, although others are of metavolcanic origin.

References

The following are publications cited in this report. A complete bibliography for the Lac la Ronge and Wapawekka areas (NTS 73P/73I) is appended to the accompanying compilation map.

Abraham, A. and Lewry, J.F. (1981): La Ronge Project: I. Geology of the Otter Lake area; in Summary of Investigations, 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p26-27.

Forsythe, L.H. (1968): The geology of the Stanley area (west half) (Mackay Lake area); Sask. Dep. Miner. Resour., Rep. 115 (Pt.1).

__________ (1971a): The geology of the Clam Lake area (west half); Sask. Dep. Miner. Resour., Rep. 136.

__________ (1971b): The geology of the Nemeiben Lake area (east half) and the geology of mineral deposits in the Nemeiben Lake - Stanley areas; Sask. Dep. Miner. Resour., Rep. 115 (Pt.2).

__________ (1972): The geology of the Clam Lake area (east half); Sask. Dep. Miner. Resour., Rep. 138.

__________ (1981): Geology of the La Ronge - Hunter Bay - Cartier Lake area; Sask. Dep. Miner. Resour., Open File Rep. 81-1.

Fumerton, S., Stauffer, M.R. and Lewry, J.F. (in press): The Wathaman Batholith: largest known Precambrian pluton; Can. J. Earth Sci.

Hoffman, P.H. (1981): Autopsy of Athapuscow Aulacogen: a failed arm affected by three collisions; in Proterozoic Basins of Canada, ed. F.H.A. Campbell; Geol. Surv. Can., Pap. 81-10, p97-102.

Lewry, J.F. (1981a): Lower Proterozoic arc-microcontinent collisional tectonics in the Western Churchill Province; Nature, v294, no5836, p69-72.

__________ (1981b): La Ronge Project: II. Geology of the Stanley Shear Zone; in Summary of Investigations, 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p28-33.

__________ (1983): Character and structural relations of the 'McLennan Group' meta-arkoses, McLennan-Jaysmith Lakes area; in Summary of Investigations, 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p49-55.

Lewry, J.F. and Sibbald, T.I.I. (1980): Thermotectonic evolution of the Churchill Province in northern Saskatchewan; Tectonophysics, v68, p45-82.

Lewry, J.F., Stauffer, M.R. and Fumerton, S. (1981): A Cordilleran-type batholithic belt in the Churchill Province in northern Saskatchewan; Precambrian Res., v14, p277-313.

Lewry, J.F., Sibbald, T.I.I. and Schledewitz, D.C.P. (in press): Reworking of Archean basement in the Western Churchill Province, and its significance; in Archean Supracrustal Sequences, ed. L.H. Ayres et al.; Geol. Assoc. Can., Spec. Publ.

Mawdsley, J.B. and Grout, F.F. (1951): The geology of the Stanley map area; Sask. Dep. Miner. Resour., Rep. 4.

Money, P.L. (1965): The geology of the area around Needle Falls, Churchill River; Sask. Dep. Miner. Resour., Rep. 88.

Morris, A. (1963): The geology of the Trout Lake area (west half); Sask. Dep. Miner. Resour., Rep. 77.

__________ (1965): The geology of the Black Bear Island Lake area (east half); Sask. Dep. Miner. Resour., Rep. 86.

Padgham, W.A. (1966): The geology of the Wapawekka Narrows area (north half); Sask. Dep. Miner. Resour., Rep. 87.

____________ (1967): The geology of the Wapawekka Lake area (north half); Sask. Dep. Miner. Resour., Rep. 103.

Project 8401A

Bedrock Compilation, Greater Beaverlodge Area (NTS 74N-6 to -11)

by R. Macdonald

Macdonald, R. (1984): Bedrock compilation, Greater Beaverlodge area (NTS 74N-6 to -11); *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The geology of the greater Beaverlodge area has been summarized on an interim 1:100,000 scale map compiled almost entirely from GSC and SGS mapping by the author and W.L. Slimmon (accompanying package). This area is difficult to compile, not only because of the different styles of the numerous geologists who have worked there, but because of the complexity of intrusive, granitizing, anatectic and structural reworking events represented, some of which are not fully understood. In addition to previous work, the author spent two weeks this summer checking in the area and is grateful for helpful discussions on the outcrops with S. Roscoe, J. Hoeve, H.E. Hendry, P.K. Mazimhaka and M.W. Thomas, and subsequent discussions with T.I.I. Sibbald. These notes describe some of the features examined this summer; lithological details are given in the legend on the accompanying map. A comprehensive report is expected to be issued later.

Mylonitized and Mixed Supracrustal Rocks (Unit Xs)

Unit Xs (this compilation legend) was first mapped in the Black Bay area by Hale (1954a) as "mylonitized rocks". In the adjoining Gulo Lake area (Hale, 1954b) his view on their status had changed, for contiguous rocks in the Gulo Lake area are indicated as "Tazin Group - dominantly quartzitic rocks with interbanded greywacke-type rocks". Scott (1978) referred to the same unit in part of the Gulo Lake area as "mylonite complex"; his descriptions include a variety of mylonites of stated precursor as well as other (presumably unmylonitized) rock types. Spot checking this summer confirmed the extreme variation in this group, ranging from ultramylonites to unsheared metasediments.

An important feature of the greater Beaverlodge area is the broad geographical coincidence between the 'successor basin' cover rocks (Thluicho Lake Group, Martin Group, etc.; see Langford, 1980) and the outcrop of unit Xs. At Ellis Bay, in fact, it is difficult to distinguish between mylonitized supracrustal rocks of the basement and the overlying lower grade Thluicho argillites and metasiltstones. Presumably similar difficulties were met during the original mapping elsewhere in the compilation area. The problem is complicated by the fact that part of the Thluicho rocks may have been involved in the shearing and mylonitization affecting the basement. It has been speculated that this took place in relatively brittle basement contemporaneously with more plastic deformation in the overlying successor basin rocks, perhaps to some extent in response to stress interactions between cover and basement (S. Roscoe, pers. comm.)

Milliken Lake Northwest

Strong shearing and mylonitization are present along the margins of the Black Bay Fault. This shearing is not uniformly distributed, as there are enclaves of relatively unsheared precursor rock, mainly feldspathic and siliceous banded gneisses, quartzites and lesser amphibolite. Siliceous and chloritic gneisses examined farther southeast along the road to Milliken Lake and around the shores of Milliken Lake are similarly heterogeneously sheared and 'ribboned'. A tectonic enclave contains recognizable conglomerate. According to Sibbald (pers. comm.) similar shearing effects extend to just southeast of Milliken Lake. On this basis the contact between rocks of the Nevins Lake Block and the St. Louis Cataclastic Belt (Thomas and Macdonald, 1983, Macdonald, 1983) can now be more firmly drawn almost down the middle of the Crackingstone Peninsula.

Black Bay Straight Belt

Examination of the shore of Black Bay confirmed the presence mainly of banded gneisses (unit FB). At Bushell Inlet the bands range from leucocratic quartzofeldspathic to mafic, and in dimension from several metres wide to millimetre-scale delicate layering. The mafic rocks are the strike extension of Tremblay's (1972) amphibolites (his units 16 and 18), and probably represent original flows or sills. Calc-silicate rocks and quartzite layers also occur. Although dipping subvertically and striking very uniformly in the northeasterly trend of the Black Bay Straight Belt (Macdonald, 1983), strong shearing in this regional trend is not widely developed and mylonites were almost only observed close to the Black Bay Fault. On this basis an approximate northwestern limit to the St. Louis Cataclastic Belt in the area south of Uranium City may be drawn coincident with the mylonites close to the Black Bay Fault (see tectonic sketch on accompanying map).

White Lake Granite

Starting about 3 km west of Bushell Inlet there is a progressive increase in anatexis towards the White Lake granite exposed on the shore and island east of St. Joseph's Point. This anatexis commences with a coarsening of grain in the more felsic bands, and passes into a distinctive feldspathoblastic rock. Selective anatexis culminates at the northwest corner of Black Bay where the granitic material has mobilized to the extent that the more mafic restite occurs as rounded and partly resorbed xenoliths. The granite here is distinctively dark brown or grey.

The White Lake granite is interpreted as a low to intermediate level anatectic intrusive complex (S-type granite), probably not far removed from its position of generation. The extent of the migmatitic fringe, now defined along the Black Bay shore, is uncertain elsewhere, although Hale's (1954b) unit 3 suggests it occurs over much of the St. Joseph's Point west of the granite outcrop.

The 'Unconformity' near Elliot Bay

A new tree-fall exposure was examined about 1 km northeast of Elliot Bay. Pink medium- to coarse-grained granitic rock (possibly Christie's unit 5) outcrops largely downhill from, as well as in the lower part of the exposure. Boulders of similar rock, together with boulders and pebbles of cream coloured cherty quartzite, vein quartz and pelitic rock, occur in the upper part of the exposure in a medium- to fine-grained matrix apparently similar in composition to the granite. The clasts are slightly deformed and the matrix is locally sheared. Quartzite with local quartz pebble horizons is mainly exposed higher on the hill. Further along strike, conglomerate horizons contain amphibolite pebbles. The matrix in the main exposure is possibly a granite wash containing fragments in an old regolith overlying a granitic basement. Alternatively, the main exposure may represent a tectonic 'roller skate' breccia.

'North Shore Plutons'

The granite exposed at the former Gunnar mine strongly resembles the Mackintosh Bay and Cameron Island granites in being coarse grained to megacrystic. Exposures visited briefly in the mine locality are variously foliated and gneissic, and locally intensely sheared in places.

'Sponge Rock' (Hematized Albite-Carbonate Dykes)

Zones of reddening associated with fracturing were encountered along the Black Bay shoreline. Strongly developed east-striking fractures on the McLean Islands are accompanied by thin mylonite zones and 'sponge rock' (hematized albite-carbonate dykes), several centimetres wide, of the type noted elsewhere in the Beaverlodge area in connection with uranium mineralization (Hoeve, pers. comm.).

Spheroidal Weathering

The basement gneisses exposed under the Martin unconformity at the former Lorado mill exhibit excellent spheroidal weathering. Similar weathering is noticeable at and immediately northwest of the Gunnar mine, signifying proximity to a now stripped off unconformable sequence, possibly the Martin or Athabasca.

Sampling for Age Determination

Samples were taken for U/Pb (zircon) determination at the Kansas Laboratories from the White Lake granite (HUD84-306), Mackintosh granite (HUD84-307), Cameron Island granite (HUD84-308), Foot Bay gneiss at Elusive Lake (HUD84-309), Stephens Lake pluton (HUD84-310 and 311), Gunnar granite (HUD84-315), and the granite at the Elliot Bay 'unconformity' exposure. In addition samples were taken from the Nolan block north of the area: Koster's (1972) Granodiorite I (HUD84-301 to 304) and Granodiorite II (HUD84-305). Results of recent Rb-Sr determinations on the Mackintosh and Cameron Island granites are given by Bell and Blenkinsop (this volume).

References

Hale, W.E. (1954a): Black Bay map-area, Saskatchewan (prelim. rep.); Geol. Surv. Can., Pap. 53-15.

Hale, W.E. (1954b): Gulo Lake, Saskatchewan; Geol. Surv. Can., Pap. 54-6 (map with descr. notes).

Koster, F. (1971): Geological investigations in the Tazin Lake region, northwest Saskatchewan, Canada; unpubl. Ph.D. thesis; summary in Ned. Akad. Wetensch., Proc., Ser. B, v74, no1, p63-92.

Langford, F.F. (1980): Successor basins in the Beaverlodge area; in Summary of Investigations 1980, Sask. Geol. Surv., Misc. Rep. 80-4, p29.

Macdonald, R. (1983): Geology and regional context of the Oldman Lake area; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p19-23.

Scott, B.P. (1978): The geology of an area east of Thluicho Lake, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 167, 51p.

Thomas, M.W. and Macdonald, R. (1983): Review geology: Prince Lake area; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p24-27.

Tremblay, L.P. (1972): Geology of the Beaverlodge mining area, Saskatchewan; Geol. Surv. Can., Mem. 367.

REVIEW GEOLOGY AND OTHER STUDIES

Project 8407

Review Geology, Stephens Lake area

by M.W. Thomas

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The Stephens Lake study area is situated 20 km east of Uranium City and encompasses about 250 km^2 in area. Previous geological investigations include 1:63,360 scale regional mapping by the Geological Survey of Canada (Christie, 1953; Blake, 1955), as well as more detailed mapping of the Beaverlodge mining area to the west (Tremblay, 1972), the Nicholson Bay - Hill Lake areas to the south (Sibbald, 1982; Macdonald et al., 1982) and the Prince Lake area to the north (Thomas and Macdonald, 1983). Over the last thirty years the area has also been subject to considerable mineral exploration activity, mainly involving radiometric surveying in the search for uranium. The present three-week study was undertaken to fill a gap in recent Saskatchewan Geological Survey mapping coverage.

Bedrock exposure in the area is greater than 50 percent and the topography is rugged, with local relief of 100 m or more. Excluding lamprophyre dykes which are restricted to the eastern part of the area, all rocks have been deformed and metamorphosed, and are broadly divisible into quartzofeldspathic migmatites, interlayered supracrustal rocks and granitoid rocks of possible plutonic origin.

Description of Rock Types[1]

Fine to coarse grained, banded quartzofeldspathic gneiss (unit Bn) is exposed in the south-central part of the area. Banding is defined by massive to foliated, medium-grained granitic leucosome layers, ranging from 1 to 50 cm thick alternating with foliated biotite ± hornblende-bearing quartzofeldspathic paleosome layers of similar thickness. The leucosome comprises 10 to 50 percent of the rock and varies in colour from pink to white, the pink variants usually occurring with hornblende-bearing gneisses. Conformable leucopegmatite is sporadically abundant. Mafic content of the paleosome ranges from 5 to 15 percent. Homogeneous, fine- to medium-grained, foliated amphibolite layers ranging in thickness from 1 cm to 2 m are generally present. These amphibolites locally contain considerable biotite and, more rarely, actinolite or diopside. Further compositional variation in the quartzofeldspathic gneisses is provided by sporadic layers of garnet-biotite schist, metaquartzite and diopside-bearing gneiss. These layers range from 1 to 50 cm in thickness and are common in some areas (subunit Bnx) but were not observed to comprise more than 20 percent of an outcrop.

Grey to white leucotonalite migmatite (unit Tn) is exposed between Max and Geebee Lakes. This unit comprises medium- to coarse-grained to pegmatitic, massive to foliated leucotonalite with paleosome bands, lenses or schlieren of garnet-biotite schist and biotite ± hornblende quartzofeldspathic gneiss. The leucotonalite contains up to 5 percent biotite as well as disseminated pyrite which produces conspicuous rusty spots on weathered outcrop surfaces. Leucosome typically constitutes at least 50 percent and, on Geebee Lake, more than 75 percent of the rock. Contacts with the surrounding gneisses are generally gradational as the amount of leucosome decreases.

Large mappable bodies of amphibolite (unit M) are similar to the thin layers in unit Bn and are themselves occasionally banded with granitic leucosome. South of Max Lake a coarse-grained, weakly foliated gabbroic body is exposed (subunit Mb). The compositional and textural homogeneity of the amphibolites suggests a plutonic/hypabyssal origin but these bodies possibly vary in both origin and age.

A variety of interlayered supracrustal rocks (unit X) is exposed in the west, between Melma and Max Lakes, and towards the east, adjacent to the Stephens Lake pluton. In the west this unit is characterized by interlayered calcareous, biotitic and feldspathic metaquartzites, calc-silicate rocks, mica schists, hornblende-bearing psammites, and amphibolites. Other than the coarsely recrystallized calc-silicates, these rocks are fine to medium grained, foliated and banded on a centimetres to tens of metres scale. There is an increase in feldspathic component from Melma Lake towards the north as feldspathic metaquartzites and psammites become more abundant. Granitic material and pegmatite locally comprise up to 20 percent of the unit in this area and, where interbanded with supracrustal material, the rocks locally resemble unit Bn gneisses. At one locality, both siliceous psammite and a nearby foliated granitoid rock were observed to be graphite-bearing, suggesting derivation of granitoids from supracrustals, at least in some cases.

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[1] Rock names used in this report and on the accompanying geological map are field names and have not been verified by modal analyses.

Toward the east, supracrustal rocks flanking the Stephens Lake pluton mainly comprise fine- to coarse-grained, banded to homogeneous, commonly rusty and graphitic garnet-biotite-quartz-feldspar gneisses of pelitic to psammitic composition (subunit Xp). Biotite content ranges from 5 to 30 percent and hornblende is absent. Red garnets, which typically constitute 5 percent of the rock, range in size from 2 mm to 1.5 cm and are commonly subidioblastic. Sillimanite was observed at a few localities. Interbanded metaquartzite, calc-silicate rock and quartzofeldspathic gneiss occur sporadically within subunit Xp, metaquartzite being especially abundant along MacRae and Forget Lakes (Blake, 1955). Amphibolite bands are generally absent. A conspicuous garnet-biotite-quartz rock containing 40 percent or more garnet (subunit Xgar) is a minor but regular constituent of subunit Xp and may represent a silicate-facies iron formation.

From the present field data, the supracrustal rocks exposed in the west and those flanking the Stephens Lake pluton to the east are to some extent lithologically distinct, and lateral continuity between the two assemblages has not been unequivocally established. Therefore, it is presently unknown whether or not the eastern and western supracrustal rocks are correlative.

Near Hayter Lake in the southeast, a body of white granite (unit WG) is exposed. This unit is equigranular, homogeneous and foliated, containing from 5 to 10 percent biotite ± rare hornblende. It locally includes massive pegmatite and enclaves of garnet-biotite gneiss, banded quartzofeldspathic gneiss and amphibolite. Contacts with adjacent rock types are sharp but cross-cutting features were not observed.

In the central and northern parts of the area, gneissic megacrystic granodiorite (unit MG) is exposed in an irregularly shaped body, here termed the Stephens Lake pluton[2]. This rock typically consists of a white to grey, medium- to coarse-grained, gneissic, homogeneous quartz-feldspar-hornblende-biotite matrix with locally interspersed microcline megacrysts ranging in size from 1 by 2 cm to 3 by 5 cm. The megacrysts are usually oval-shaped and aligned in the gneissosity, but where weakly deformed, are blocky and subidioblastic. Mafic content ranges from about 10 to 15 percent. North of the Stephens Lake fault, hypersthene occurs in the matrix with hornblende and biotite, and the rocks exhibit a waxy brown fresh surface. Bands and enclaves of fine- to medium-grained amphibolite ± hypersthene are common in this unit. The gneissic granodiorite is locally intruded by pink leucogranite and pegmatite bands which cross-cut gneissosity in places and locally comprise 50 percent of the rock (subunit MGn). Along both the west contact of the pluton and the Stephens Lake fault, the rocks are deep red to pink, gneissic to banded and commonly chlorite-bearing (subunit MGy; cf. unit R, Thomas and Macdonald, 1983). Epidote-filled fractures, fluxion structures and intensely augened relict microcline megacrysts also occur locally. Cataclasis and retrogressive metamorphic effects related to the St. Louis and Stephens Lake faults likely caused these changes, which also typify many of the rocks in the Beaverlodge area to the west (Tremblay, 1972).

A distinctive homogeneous, fine- to medium-grained, commonly porphyroblastic pink granite (unit PG) is exposed in the southwest part of the study area. This unit contains from 5 to 10 percent biotite (commonly chloritized) and is generally weakly foliated, although massive, coarsely gneissic and sheared varieties also occur. Pink K-feldspar blasts are generally augened and measure about 0.5 by 1 cm in size. Pink massive pegmatite and leucogranite are locally abundant. Sporadic enclaves of diopsidic quartzofeldspathic gneiss, amphibolite and metaquartzite usually exhibit sharp border contacts, although some examples of diffuse contact relationships gradational over one metre were observed and are considered to represent incipient assimilation of the enclave. Similarly, contacts with the country rocks are usually sharp and commonly sheeted but are locally gradational over 100 m where an heterogeneous banded to massive quartzofeldspathic rock occurs. Areas comprising variable proportions of pink granite and country gneisses were mapped as intrusive complexes (subunit PGn). Their contacts are gradational and somewhat arbitrary, as the amount of granite varies considerably. Larger disoriented amphibolite bodies are common in these complexes.

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[2] The southeast contact of this body has not yet been mapped and its eventual size and shape is unknown. It is noteworthy that examination of 1:60,000 scale airphotos in conjunction with Blake's (1955) regional geological map indicates the possibility that this body is also exposed northeast of Forget Lake and east of the Oldman River. In this case, supracrustal rocks exposed at Forget and MacRae Lakes and south along the Oldman River would be septa of country rock within the plutonic mass, similar to the band of supracrustal rocks passing through Hutton Lake.

Structure and Metamorphism

Two major penetrative deformational events are recognized in the area. The foliation, gneissosity and/or banding exhibited by most rock types conforms to lithological contacts and represents the earliest (S_1) tectonic fabric identified. Mesoscopic isoclinal folds tentatively related to this event (D_1) were observed in unit X at two localities northeast of Melma Lake, one of which was overprinted by later (D_2) coaxial folds to produce a Type 3 fold interference pattern (Ramsay, 1967). The presence of major D_1 fold closures is not apparent from the geological map.

Most major and minor folds are related to the D_2 event and deform the S_1 fabric about moderately-plunging, southwesterly-trending axes and steeply-dipping axial surfaces. This D_2 episode produced broad, open warps in the rocks west of and along the border of the study area but, within the area, fold amplitudes are larger and closures are generally tight to isoclinal. An S_2 foliation oblique to S_1 is only locally observed, usually in major D_2 fold noses. Northeasterly-trending foliation in unit PG north and east of Bearcat Lake may also be of D_2 age as it appears to cross-cut structural trend lines conspicuous on airphotos, which conform to east-west trending S_1 banding in rocks to the south (Macdonald et al., 1982). Mineral lineations and rodding structures parallel to D_2 minor fold axes are quite common. However, these linear structures may be, in part, of D_1 age, as it is possible the two folding events were coaxial.

Folds postdating D_2 structures were not identified in the study area. However, subsequent cataclastic deformation associated with regional fault zones has re-oriented, overprinted and destroyed earlier structural elements in some areas, especially nearer the St. Louis fault.

Regional metamorphism attained granulite facies conditions in the northeast, as indicated by the appearance of hypersthene in unit MG north of the Stephens Lake fault. South of this fault only biotite and hornblende occur in this unit. Upper amphibolite conditions are indicated in the south by the appearance of sillimanite in subunit Xp. Blake (1955) previously documented this upper amphibolite to granulite facies increase in metamorphism from west to east across the Oldman River area. Hypersthene-bearing pegmatites, which locally define an S_1 fabric in unit MG, suggest that this metamorphism was initiated during the D_1 deformational event.

Retrograde metamorphism related to late cataclastic deformation produced reddened feldspars, chloritized mafics and epidote-filled fractures in rocks adjacent to the many lineaments which cut the area. These effects are especially prominent adjacent to the St. Louis fault and, to a lesser extent, the Stephens Lake fault. Lamprophyre dykes (unit La) observed in the area are unaffected by this later retrogression and cataclasis, although Blake (1955) reports a dyke west of Forget Lake with a sheared contact.

Economic Geology

Most rocks in the area are quartzofeldspathic in composition and have undergone high-grade regional metamorphism. These two facts conspire to render the area economically uninteresting. During previous mineral exploration, lineaments and faults have been intensively prospected for uranium mineralization with little success. Yellow uranium oxides were observed on fractures at two localities in subunit PGn. Disseminated barren sulphides occur sporadically in pelitic schists of unit X and chalcopyrite was noted in psammitic gneiss north of Melma Lake. Graphite comprises up to 10 percent of mica schists and gneisses of subunit Xp along, and one kilometre west of, Hayter Lake.

References

Blake, D.A.W. (1955): Oldman River map-area, Saskatchewan; Geol. Surv. Can., Mem. 279.

Christie, A.M. (1953): Goldfields - Martin Lake map-area, Saskatchewan; Geol. Surv. Can., Mem. 269.

Macdonald, R., Thomas, M.W. and Lee, N. (1982): Geology of the Hill Lake area; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p8-11.

Ramsay, J.G. (1967): Folding and fracturing of Rocks; McGraw-Hill, New York, 568p.

Sibbald, T.I.I. (1982): Uranium metallogenic studies: Nicholson Bay area; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p43-45.

Thomas, M.W. and Macdonald, R. (1983): Review geology: Prince Lake area (part of NTS 74N-9); in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p24-27.

Tremblay, L.P. (1972): Geology of the Beaverlodge mining area, Saskatchewan; Geol. Surv. Can., Mem. 367.

Project 8401B

Review Geology, Forbes Lake Vicinity

by R. Macdonald

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Two weeks were spent this summer in the area between Larocque, Forbes, McIntosh, Mountney, Nipew and Devil Lakes reviewing earlier mapping, partly as a contribution to the compilation of the Lac la Ronge (NTS 73P) sheet area (Lewry, this volume). One objective was to examine the northwestern margin of the Central La Ronge Metavolcanic Belt along Larocque and Forbes Lakes. Lewry (1983) had indicated the existence of a regional-scale shear zone, the McLellan Lake Thrust, along the southeastern margin of this belt, and a feature of similar magnitude was suspected to exist on the northwestern margin.

Larocque Lake

Pearson and Froese (1959) showed the shores of Larocque Lake to be underlain by volcanic rocks. As reviewed this summer, these metavolcanics comprise fine-grained flows, tuffs and porphyries, which strike uniformly to the northeast and dip steeply or moderately steeply to the northwest, apparently as part of a regional homocline. Primary features such as amygdales and relict phenocrysts are present, and a coarse agglomerate with felsic clasts up to 25 cm long occurs at the south end of the lake. These rocks have all attained amphibolite facies grade.

Although 'straightened' parallel to the long axis of the lake, most of these rocks do not appear to be strongly deformed, as penetrative tectonic foliation is generally weak, minor folds were not encountered and few lineations were observed. The contact with the Ismond Lake granite appears to be relatively unsheared and is marked by a zone of xenolith assimilation.

Forbes Lake North

The northern shores and islands of Forbes Lake expose a variety of felsic rocks. Pale siliceous fine- to medium-grained, finely laminated and slightly flaggy quartzofeldspathic rock occurs on islands in the centre of the lake (sf).1 Relict feldspar phenocrysts, partly sheared quartz eyes and disc-like aggregates of biotite are common constituents. This rock is considered to be a slightly sheared and foliated equivalent of the rhyolitic rocks at Larocque Lake (rh).

Fine- to medium-grained 'felsite' (rh,sfx) sills or flows, in places with fine fluxion (flow) texture, occur in narrow bands a metre or two thick.

Most rocks encountered on Forbes Lake are felsic or intermediate, fine to medium-fine grained and variably textured. Phenocrysts of partly sheared and granulated feldspar and quartz are common (fv,av). At several locations a darker grey rock (probably andesite) was observed to contain amygdales. A commonly occurring rock (fvt) contains pervasive but locally impersistent layers and lenses of coarser intermediate material in a finer and slightly more felsic groundmass; the layers typically average 2 to 5 mm in thickness, repeated at intervals of about one or two centimetres. This texture is possibly inherited from tuff or ashflow tuff.

Some of the felsic rocks show fine 'ribbing' on the weathered surface (fvr), mainly due to primary fluxion texture rather than tectonism.

A medium-fine grained uniform grey biotitic quartzofeldspathic rock (gg), occurring largely between Bateman Lake and the northern end of Forbes Lake, may have either a volcanic ('andesitic') or greywacke-tuff precursor.

Mafic rocks comprise massive amphibolite with calc-silicate lenses and compositionally banded gneisses. These are probably entirely metavolcanic, primarily basaltic flows and banded tuffs (mv,mt,mba,mct). The mafic tuffs are typically heterolithic fine- to coarse-banded rocks, locally with fine- and coarse-grained material in irregular alternate bands which are considered to approximate original bedding. Where these coarse bands exceed more than a few centimetres in thickness the rock resembles gabbro. Mixed (mafelsic) tuffs (mtf) also occur.

1These and subsequent codes refer to rock types placed in the Precambrian Original Data file in Regina (N. Lee).

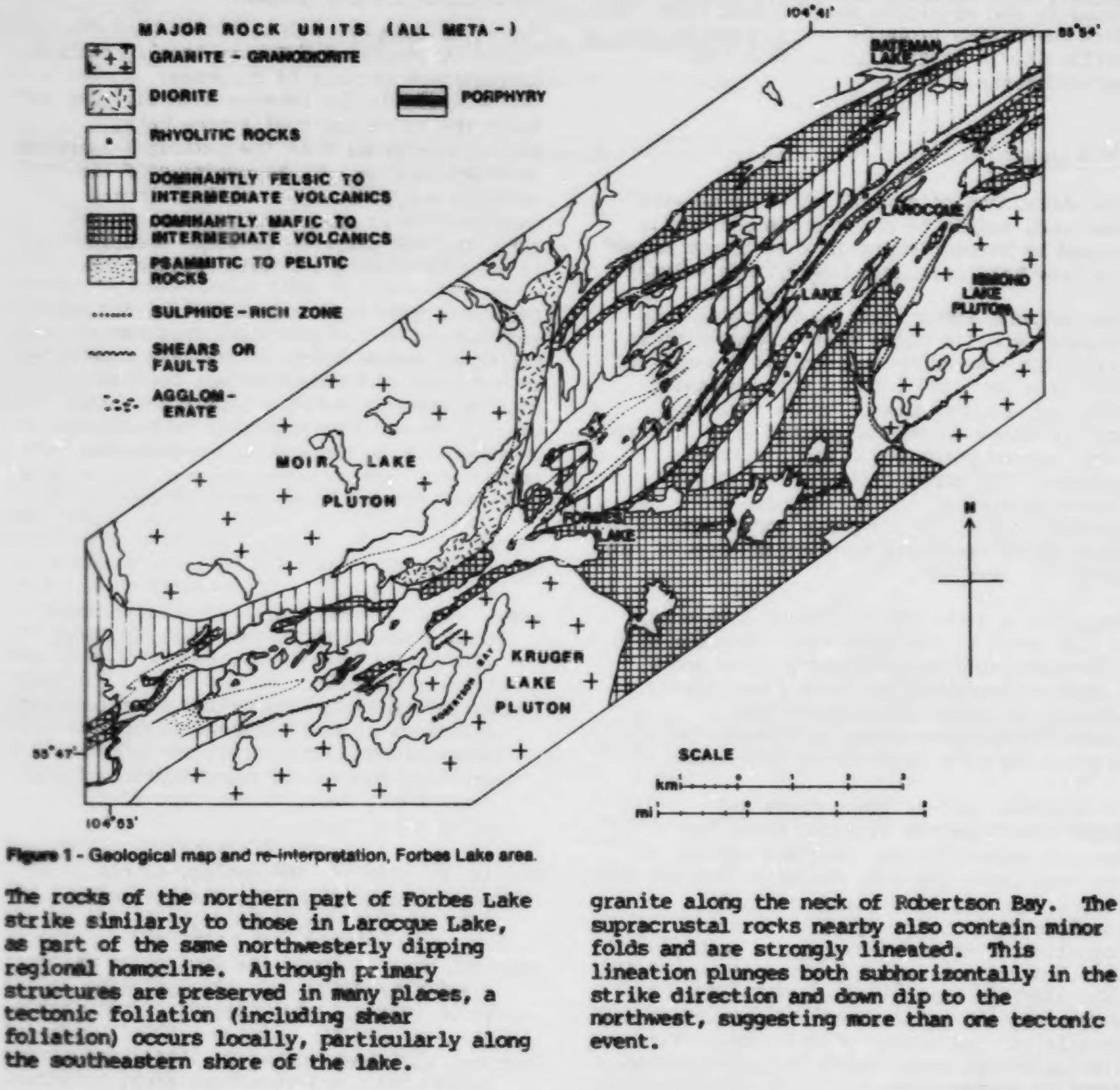
MAJOR ROCK UNITS (ALL META-)
GRANITE - GRANODIORITE
DIORITE
PORPHYRY
RHYOLITIC ROCKS
DOMINANTLY FELSIC TO INTERMEDIATE VOLCANICS
DOMINANTLY MAFIC TO INTERMEDIATE VOLCANICS
PSAMMITIC TO PELITIC ROCKS
SULPHIDE-RICH ZONE
SHEARS OR FAULTS
AGGLOMERATE
104°41'
55°54'
BATEMAN LAKE
LAROCQUE
LAKE
LAKE PLUTON
MOIR LAKE
PLUTON
FORBES LAKE
ROBERTSON BAY
KRUGER
LAKE
PLUTON
N
SCALE
km
mi
55°47'
104°53'

Figure 1 - Geological map and re-interpretation, Forbes Lake area.

The rocks of the northern part of Forbes Lake strike similarly to those in Larocque Lake, as part of the same northwesterly dipping regional homocline. Although primary structures are preserved in many places, a tectonic foliation (including shear foliation) occurs locally, particularly along the southeastern shore of the lake.

Forbes Lake South

Along the southern half of Forbes Lake the metavolcanic and tuffaceous rocks are interspersed with rusty pelites, psammopelites (ps), banded rocks of less certain origin (mix,swbi) and what appear to be flaggy psammites (rn). Granitic dykes and masses also occur. Sills of fine-grained granitic porphyry occur on the islands opposite Robertson Bay.

Shearing is more pronounced here than in the northern part of Forbes Lake. Parts of the western contact of the Kruger Lake pluton are sheared and zones of shearing occur in the granite along the neck of Robertson Bay. The supracrustal rocks nearby also contain minor folds and are strongly lineated. This lineation plunges both subhorizontally in the strike direction and down dip to the northwest, suggesting more than one tectonic event.

Comment

Pearson and Froese (op. cit.) mapped the rocks around Forbes Lake wholly as metasediments, including quartzite and greywacke. The author believes that most rocks seen this summer along the northern part of Forbes Lake and a significant number in the southern part of the lake are metamorphosed volcanic flows, sills or pyroclastics of felsic to intermediate composition. Metasediments occurring in the area are probably mainly in the tuff-sediment transition. The 'hornblende and calc-silicate gneisses' of Pearson and Froese are derived largely from mafic and associated metavolcanics. The Forbes Lake rocks are locally more deformed and recrystallized than those in the adjoining metavolcanic belt. This factor has probably contributed to the difficulty in distinguishing them from metasediments.

Other Areas

The shorelines of several other lakes were examined, mainly to check rocks originally mapped as metasediments in what is now termed the Crew Lake belt (cf. Lewry, this volume).

The volcanic rocks striking southwest from Renwick Lake lie close to the metasediments previously mapped by Pearson and Froese (op. cit.) and Ray (1981) along the southeast shore of McIntosh Lake. These include uniform fine- to medium-grained grey biotitic rock, banded hornblendic and biotitic gneisses, and amphibolite. Fine garnet occurs in some of the hornblendic and biotitic rocks. Sillimanite and muscovite, which would confirm a sedimentary origin, were not observed.

Metamorphic rocks of convincing sedimentary origin occur on Mountney Lake, together with grey-green tuffaceous-looking rocks and a magmatic complex of at least five intrusive phases. A basic intrusion on the southeastern shore shows well preserved regular rhythmic bands about 4 cm apart.

Hornblendic calc-silicate rocks and associated supacrustal rocks along the central parts of Nipew lake are similar to the hornblende gneisses mapped by Pearson and Froese (op. cit.), and are similarly interpreted as volcanogenic. Several magmatic phases are also exposed on Nipew Lake. Granite along the northeast arm of the lake displays multiple shear foliations suggesting the presence of a major shear zone parallel to the length of the lake. Features similar to all those found in Nipew Lake also occur on Hayman Lake.

On Devil Lake there is a transition across the McLelland Lake thrust from meta-arkose of the McLennan Group (Lewry, op. cit.) northeasterly to grey andesitic rocks which are well exposed at the rapids. The 'mafic sediments' of Padgham (1960) exposed on the northeastern side of Devil Lake appear to be mafic tuffs and flow rocks.

Implicatons for Exploration

The hornblende and calc-silicate gneisses mapped by Pearson and Froese locally contain considerable amounts of sulphide, particularly in the Bateman Lake vicinity and along the south shore of Forbes Lake. Although pyrrhotite is the principal sulphide recorded to date, the recognition of the volcanic environment, as well as their constitution as an iron-formation (Harper, 1983) and the presence of local shearing are factors favourable for gold exploration.

Perhaps a more important potential for gold exploration is the postulate that rocks mapped as metasediment in the Crew Lake belt in and west of Forbes Lake may contain significant amounts of volcanic material. Many of these rocks appear to be felsic to intermediate in the volcanic-sedimentary transition. Comparisons may possibly be made with the regional environment at Hemlo.

References

Harper, C.T. (1983): Iron ores of northern Saskatchewan; Sask. Energy Mines, Rep. 220.

Lewry, J.F. (1983): Character and structural relations of the 'McLennan Group' meta-arkoses, McLennan-Jaysmith Lakes area; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p49-55.

Morris, A. (1960): The geology of the Trout Lake area (east half), Saskatchewan; Sask. Dep. Miner. Resour., Rep. 42.

Padgham, W.A. (1960): The geology of the Otter Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 41.

Pearson, W.J. and Froese, E. (1959): The geology of the Forbes Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 34.

Ray, G.E. (1981): Geology of the Foster Lake (south) - La Ronge (northwest) area; Sask. Miner. Resour., Rep. 185.

Project 8403

The Martin Group, Beaverlodge Area

by P.K. Mazimhaka[1] and H.E. Hendry[1]

Mazimhaka, P.K. and Hendry, H.E. (1984): The Martin Group, Beaverlodge area; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The area of the present study of the Martin Group and related rocks extends from the shores of Beaverlodge Lake to Tazin Lake in the north, Jug Bay in the southwest and Charlot Point in the west (Fig. 1). During the 1984 field season, work was confined mainly to the vicinity of Uranium City, where detailed stratigraphic sections were measured through the four formations of the Martin Group (Fig. 2).

Parts of the Martin Group have been studied and mapped several times in the past, most notably by Tremblay (1972). Maps and surveys of adjacent areas of the Martin Group and crystalline basement have been made by Christie (1953), Langford (1981) and Sibbald and Lewry (1980). A compilation geological map at 1:100,000 scale is also available (Macdonald, this volume). Sedimentological studies of the Martin have been conducted by Elliott (1982), Langford (1981) and Macey (1973). The stratigraphic subdivisions of Langford (1981) have been used in this report.

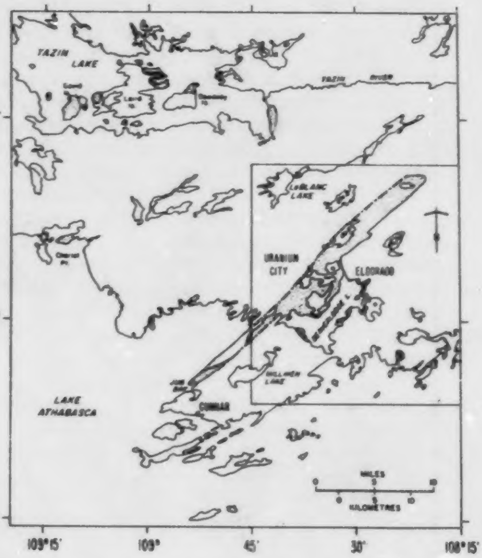

Figure 1 - Location map of the Martin Group, Greater Beaverlodge area.

Sub-Martin Unconformity

The unconformity below the sedimentary rocks of the Martin Group was developed on the granitic, quartzitic and amphibolitic rocks referred to in earlier reports as the Tazin Group. The irregular topography of the unconformity, emphasized by Tremblay (1972), Langford (1972) and Macey (1973), is particularly well displayed east and southeast of Eldorado, around the Lorado mill, along the Lodge Bay road south of Beaverlodge Lake and east of Fredette Lake. Mapping of the unconformity has shown that the conglomerates and breccias in the lower part of the Beaverlodge Formation fill steep-sided basins up to 1000 m deep. In the vicinity of Eldorado townsite and the Fay shaft, and southwards towards Umisk Island, the basement surface forms a series of ridges and valleys along an eastward-facing scarp. The scarp is up to 300 m high but erosional relief on the surface could have been much less if the scarp developed by faulting during deposition of the Beaverlodge. In the area of the Lorado mill the basal breccias of the Beaverlodge fill a re-entrant in a 1400 m high scarp which faces southwest. The erosional relief that must have existed before deposition of the Martin Group is very difficult to determine.

Beaverlodge Formation

The Beaverlodge Formation (Langford, 1981) includes all of the basal conglomerate and part of the lower arkose of Tremblay (1972). The nature and thickness of the formation, and its relationship to the underlying basement, vary from place to place. The best picture of the features of the formation is obtained if it is described separately at each of the localities where it is well developed. There are good exposures of the Beaverlodge Formation around the Fay shaft and Eldorado townsite, along the south side

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[1] Department of Geological Sciences, University of Saskatchewan, Saskatoon. Project supported by contracts with the Saskatchewan Geological Survey in 1983-85.

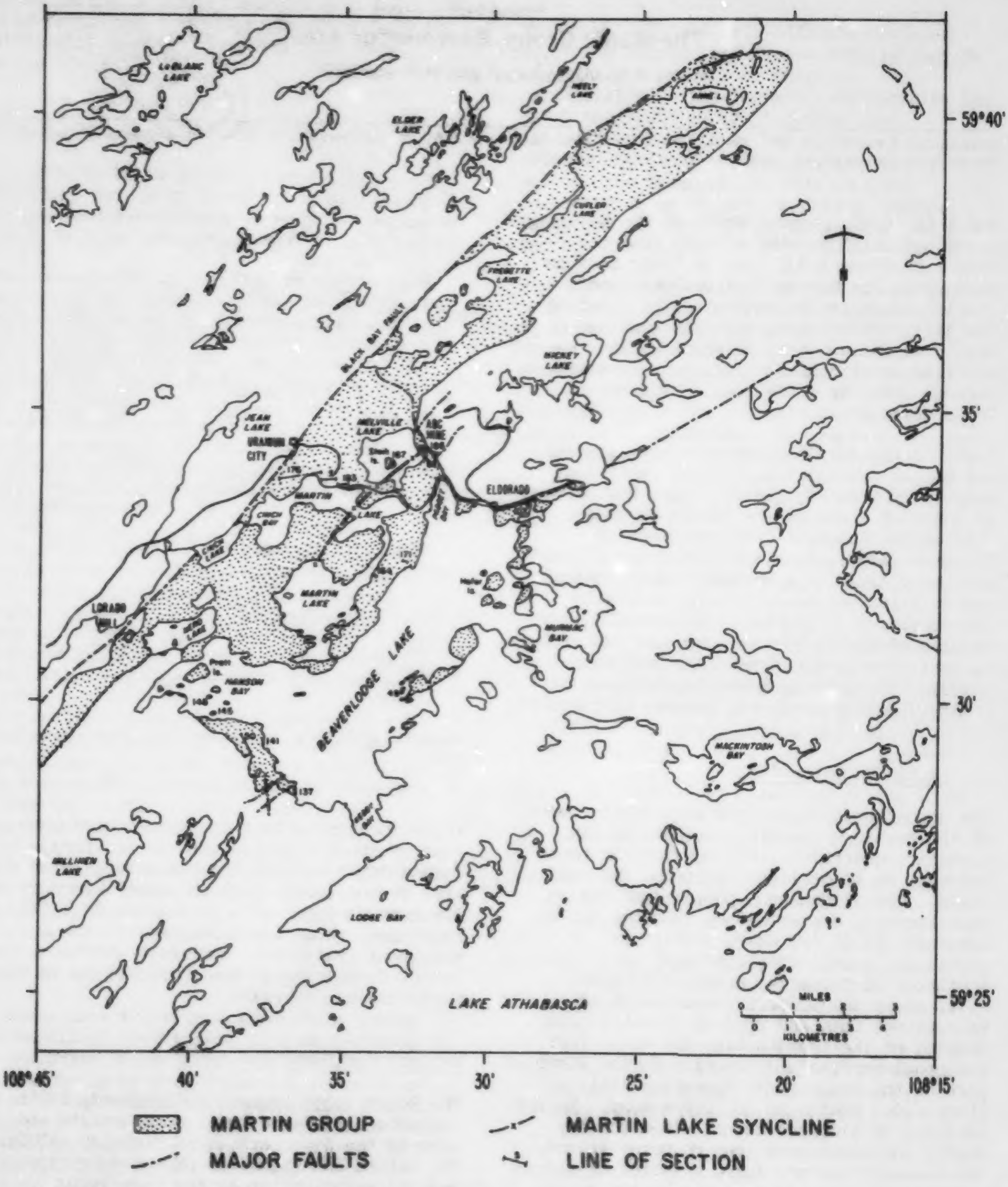
LeBLANC LAKE
NEELY LAKE
ELDER LAKE
ANNE L.
CUTLER LAKE
FREDETTE LAKE
BLACK BAY FAULT
NICKEY LAKE
JEAN LAKE
MELVILLE LAKE
ABC MINE
URANIUM CITY
MARTIN LAKE
ELDORADO
CINCH BAY
CINCH LAKE
LORADO MILL
HANSON BAY
MURMAC BAY
BEAVERLODGE LAKE
MACKINTOSH BAY
MILLIKEN LAKE
LODGE BAY
LAKE ATHABASCA
MILES
0
1
2
3
0
1
2
3
4
KILOMETRES
59°40'
35'
30'
59°25'
108°45'
40'
35'
30'
25'
20'
108°15'
MARTIN GROUP
MAJOR FAULTS
MARTIN LAKE SYNCLINE
LINE OF SECTION

Figure 2 - Outcrop map of the Martin Group, Greater Beaverlodge area.

of Beaverlodge Lake, on Umisk Island and the neighbouring mainland, near Lorado mine and mill, and around Fredette and Anne Lakes (Fig. 2).

Fay Shaft and Eldorado:

Near the Fay shaft the basal conglomerate is thin and contains beds of siltstone (0 to 37.5 m in Fig. 3); clast size decreases upwards from cobble (249 mm) to pebble (44 mm) and the thickness of siltstone beds increases upwards from a few centimetres to 20 m (Fig. 3). Individual conglomerate beds are finer grained towards their tops; bedding is mainly horizontal but there are a few planar crossbeds. Above the interbedded siltstone and conglomerate (37.5 m to 53.5 m) there are thin, lenticular cobble-grade (140 mm to 250 mm) conglomerates interlayered with medium- to very coarse grained sandstones. Bed thickness of the sandstones increases up-section. The sandstones and siltstones contain load deformation structures, wave and current ripple marks, sandstone dykes and desiccation cracks. The section is topped by a thick conglomerate (37.5 m to top) that passes into pebbly sandstones and interbedded sandstones and siltstones to the southwest.

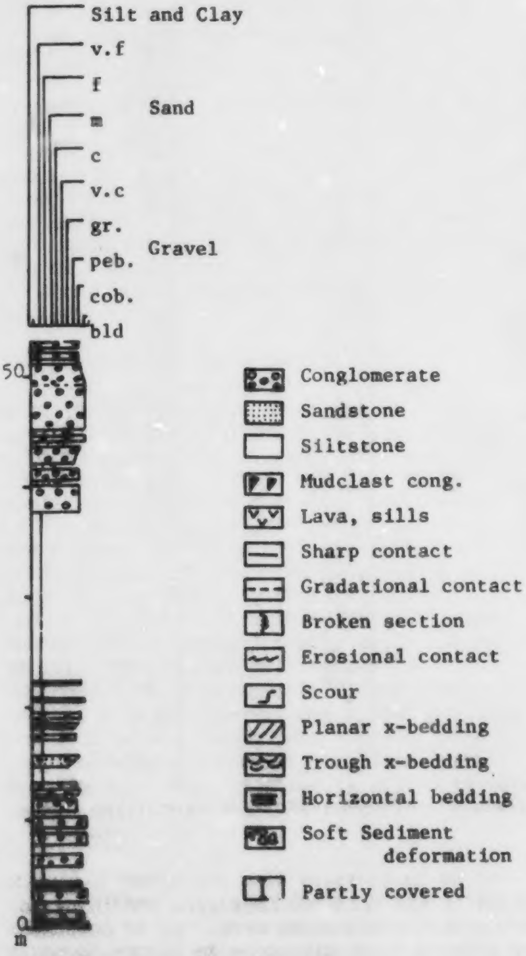

Figure 3 - Stratigraphic section of the lower part of the Beaverlodge Formation north and west of the Fay shaft, Eldorado mine (locality 107 on accompanying map).

South of Beaverlodge Lake:

In this area the lowermost 21.5 m of the formation are composed of cobble conglomerates interbedded with coarse-grained and very coarse grained sandstones; bed thicknesses are from 1 to 4 m for the conglomerates and from 2 to 5 m for the sandstones (Fig. 4). From 21.5 m to 126 m the rocks are well-bedded and well-sorted cobble conglomerates which become finer grained up-section; the conglomerates generally overlie scoured surfaces on thin sandstone beds. The rest of the measured section consists of 370 m of pebbly sandstone, pebble- and cobble-grade conglomerates and coarse-grained sandstone, with abundant trough cross-bedding, scour channels, planar cross-bedding, horizontal bedding and some ripple cross-lamination. When allowance is made for gaps in the middle and top of the section, the total thickness of the Beaverlodge Formation here is estimated to be about 1150 m. Paleocurrents from the trough cross-bedding indicate southwesterly flow.

Umisk Island and Surrounding Area:

On Umisk Island and on the mainland to the northwest, the basal conglomerate is cobble to boulder grade and is up to 300 m thick. It is very crudely bedded and poorly sorted, and contains some imbrication indicating flow to the southeast. Deposition was on southeasterly-facing scarps with slopes of up to 60°. On the peninsula to the southwest of Umisk Island, the basal conglomerate is very thin and accumulated on a surface with a slope of less than 20° to the south. It appears that the thickest conglomerates were deposited on topographically lower parts of the pre-Martin surface, perhaps on the downthrown sides of faults.

Lorado Mill and Surrounding Area:

The basal conglomerate in the area of the Lorado mill may be as much as 1500 m thick, although the rock is very poorly bedded and in many places it is impossible to measure dip and strike, thereby making estimates of thickness difficult. The scarp against which the conglomerates were banked was steep and faced south. Changes in clast composition up-section from predominantly quartzitic to granitic indicate gradual unroofing of the granitic rocks presently exposed in spheroidally weathered masses at the Lorado mill.

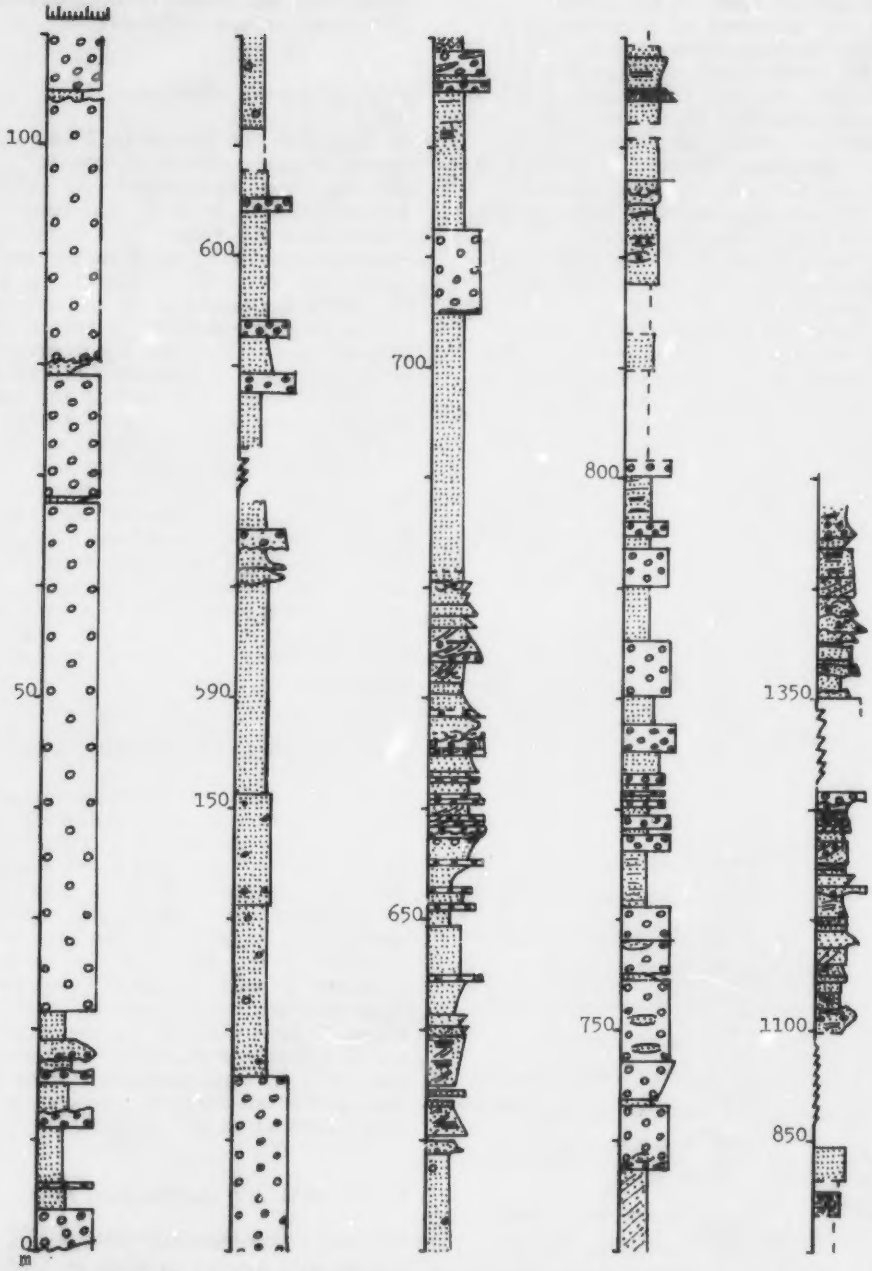

Figure 4 - Stratigraphic section of the Beaverlodge Formation south of Beaverlodge Lake (localities 137, 141, 50, 145 and 146 on accompanying map).

Fredette Lake and Anne Lake:

The Beaverlodge Formation is poorly exposed in these areas but the basal conglomerate overlies a fairly even surface of low relief. The conglomerate is about 600 m thick in the Fredette Lake area and thins to 400 m in the Anne Lake area. It is overlain by a 300 m thick siltstone in the Fredette Lake area and an 800 m thick sandstone. In the Anne Lake section there is no siltstone and the sandstone is up to 500 m thick.

Within the conglomerates of the Beaverlodge Formation there is a wide range of textures and structures. Where the basal conglomerate of Tremblay (1972) is thick, it is poorly sorted and poorly bedded and contains such angular clasts in some places that it would be better termed a breccia; deposition likely was as talus, or from rock falls or torrential floods. Higher in the formation, the conglomerates are better sorted, contain mainly rounded clasts, and are both horizontally and cross-bedded; they are interbedded with sandstones and thin siltstones and were likely deposited in braided streams.

Gillies Channel Formation

Elliott (1982) subdivided the Gillies Channel Formation into a basal conglomerate (500 to 600 m), a central sandstone (800 to 1500 m) and an upper sandstone and volcanic unit (800 m).

The conglomerate is exposed best on Pratt Island in the west and on small islands off the eastern shore of Beaverlodge Lake, but the central sandstone is very poorly exposed around Padget Bay and north of Nero Lake. The estimated thickness of the conglomerate and sandstone is 1000 m in the Beaverlodge and Nero Lakes area, and at least 1500 m between Gillies Channel and the islands south of Hofer Island.

The central sandstone consists of coarse-grained sands, grey to red and purplish-grey pebbly sandstones, and pebble to small cobble conglomerates; it is poorly exposed and mostly covered by the waters of Beaverlodge Lake. The lower part of the sandstone is interbedded with conglomerates on the small islands off the eastern shore of Beaverlodge Lake (Fig. 5). It occurs as horizontally and cross-bedded units up to 30 cm thick. The conglomerates are well bedded (0.50 to 1.50 m thick), well sorted and of pebble to small cobble grade (30 to 95 mm). The cobbles are rounded to subrounded and some appear to have been derived from the Beaverlodge Formation. The contacts between sandstones and overlying conglomerates are commonly erosional with deep scours. The sandstone is coarse to very coarse and grey, chocolate brown, greyish-green or purple.

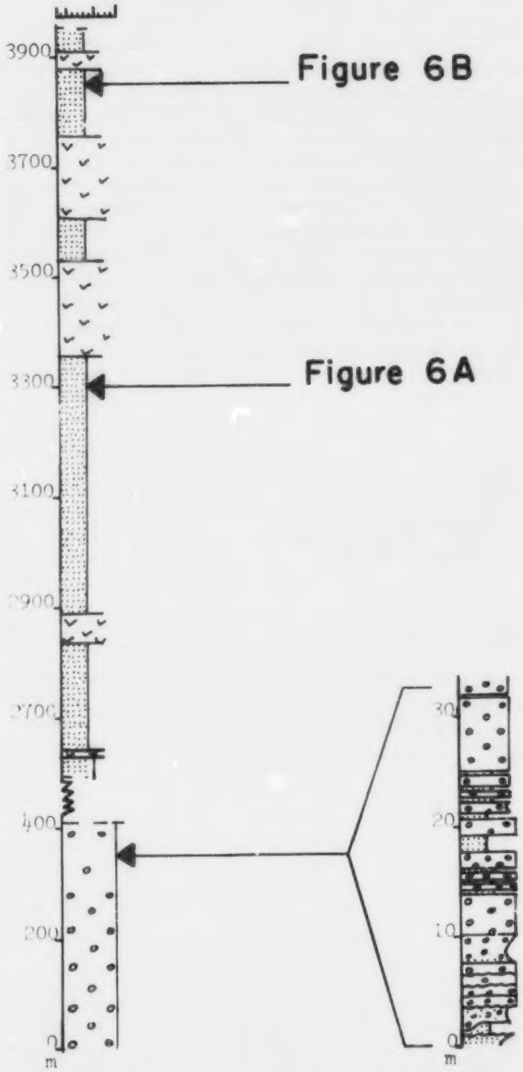

Figure 5 - Stratigraphic section of basal conglomerate and part of central sandstone, Gillies Channel Formation, islands in the eastern part of Beaverlodge Lake (locality 49 on accompanying map).

The upper sandstone unit consists of up to six lava flows, interbedded with sills and sandstone beds. The most complete sequence, although poorly exposed, occurs along the eastern shore of Cinch Lake and the western shore of Cinch Bay (Fig. 6 and accompanying map), where three sills and three lava flows are interbedded with sandstones. The sills occur stratigraphically below the lava flows. The number of sills in the eastern part of the Gillies Channel Formation is not known. Assuming the same stratigraphic relationships throughout the formation, there may be some sills beneath Beaverlodge Lake. The flows number up to seven in the exposed section between Martin and Beaverlodge Lakes. The lava flows range from 50 to 150 m thick and Tremblay (1972) gives a comparable thickness for the sills. There is both structural and textural evidence for multiple flows within each unit, as pointed out by Tremblay (1972).

The sandstones interbedded with or intruded by volcanic rocks and gabbroic sills are generally coarse and pebbly. The rocks range from small cobble conglomerates to medium-grained arkose. Although the larger clasts (pebbles and cobbles) commonly occur at the base of sand units, in the foresets of cross-beds or scattered in the sand, there are some discrete pebble and small cobble (30 to 90 mm) conglomerate units. Silt- and clay-grade rocks are very rare in the Gillies Channel Formation. Rocks of the Gillies Channel Formation form an overall upward-fining sequence and contain a number of small-scale (5 to 10 m) upward fining sequences (Fig. 6). The commonest structures in this unit are trough cross-beds that fill steep-sided scours, planar cross-beds up to 20 cm thick, horizontal bedding and laminations. Some soft-sediment deformation was observed at one locality in the lower part of the sequence.

Seaplane Base Formation

The Seaplane Base Formation is very well exposed along the shores of Martin Lake and in roadcuts between Uranium City and Eldorado, as well as to the west and south of Uranium City (see accompanying map). The formation consists of interbedded conglomerates, sandstones and mudstones, and is conglomeratic in the western and northern parts of the Martin Lake Syncline and sandy in the south and east. The total thickness is 1800 m and both the base and top are gradational. The sandstones of the Seaplane Base Formation are distinctively more red and generally better sorted than those of the Gillies Channel Formation. Langford (1981) drew the boundary on the basis of this distinction, but Elliot argued that such a distinction was too subtle to be easily recognized in the field and favoured placement of the boundary at the top of the uppermost lava flow. Langford's boundary criteria have been used in this report.

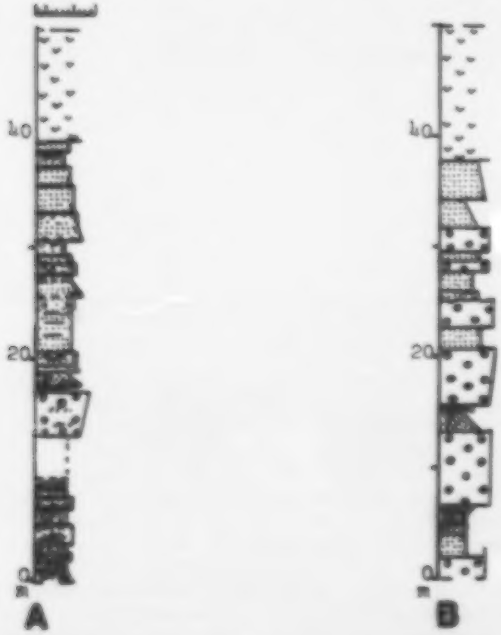

Figure 6 - Stratigraphic section of part of the upper sandstone, Gillies Channel Formation, between Beaverlodge Lake and Martin Lake (localities 171 and 184 on accompanying map).

In the best-exposed, almost continuous section through the Seaplane Base Formation, the following major subdivisions can be recognized (Figs. 5, 6 and 7):

1) A lowermost unit of conglomerate and sandstone interlayered with thin siltstone beds (only the top 17.5 m is shown in Fig. 7).

2) A middle conglomerate, up to 80 m thick, consisting of upward-fining and trough cross-bedded units. The conglomerate is commonly of small cobble to pebble (24 to 65 mm) grade. The conglomerate-sand couplets thin up-section from a thickness of up to 20 m to less than 10 m (Fig. 7, 17.5 m to 109 m). The contacts between the couplets are scoured and the intensity of scouring, steepness of foresets in trough cross-beds and number of intraformational conglomerates increase upwards.

3) A sandstone unit, up to 300 m thick, interbedded with siltstone (109 m to 400 m). The sandstone is coarse- to very coarse grained and pebbly in places.

4) The uppermost part (up to 900 m), including the transition to the Melville Lake Formation, consists of conglomerates interbedded with sandstones, and mudstone drapes on rippled sandstones and siltstones (Figs. 8 and 9). Both upward fining and coarsening units, up to 30 m thick, occur in this part of the formation. The most common structures are ripple marks, mudcracks, sand dykes, intraformational conglomerates and scours.

In the area south and east of Martin Lake (see accompanying map), the Seaplane Base Formation contains very little conglomerate and consists mainly of sandstone with some siltstone beds up to a few centimetres thick. If the formation is followed along

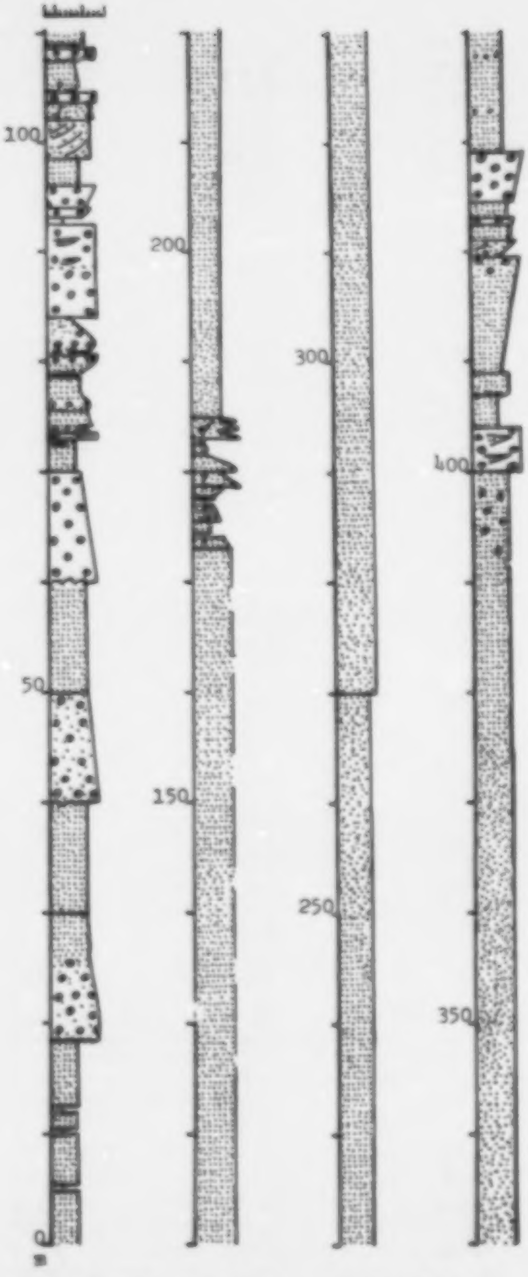

Figure 7 - Stratigraphic section of part of Seaplane Base Formation, northwest of Martin Lake (locality 178 on accompanying map). This section includes only the uppermost 17.5 m of lowermost unit in the formation. The section is continued in Fig. 8.

strike around the trend of the Martin Lake Syncline, the sequence changes from interbedded sandstones and conglomerates to trough cross-bedded sandstones with some rippled sandstones and siltstones and then to planar-bedded sandstones with some rippled beds and mud drapes. This facies change indicates dispersal of the Seaplane Base sediments from the north and northwest. In both the conglomeratic and sandy parts of the formation, there is abundant evidence of repeated changes in the flow power, during which periods of gravel or sand transport alternated with periods of stagnation and mud deposition. Most of the Seaplane Base Formation has been interpreted as the product of deposition by repeated floods in a system of interconnected channels. Paleocurrent directions from cross-bedding indicate a mainly southeasterly flow.

Melville Lake Formation

The Melville Lake Formation includes all of Tremblay's (1972) siltstone member (Unit 26). He described it as a chocolate red siltstone interbedded with arkose and conglomerate.

The formation is well exposed in the road cuts along the Uranium City - Eldorado road, on Stoik Island and in the vicinity of the ABC mine. The base of the Melville Lake Formation is gradational and marked by an increase in the thickness of siltstone beds, as well as an abrupt colour change from pink to brown. The transition from the Seaplane Base Formation is fairly well exposed at the Fredette Lake road junction and in outcrops along the Fredette Lake road. The eastern part of the sequence is not so well exposed, but some of the lowermost rocks crop out by the Melville Lake road junction.

Whereas the southern part of the Melville Lake Formation is chocolate red (Tremblay, 1972) and dark red to maroon (Langford, 1983), the central and northeastern part is rather reddish pink and very similar to the Seaplane Base Formation.

Short sections (50 to 80 cm) have been measured along the Eldorado road, on Stoik Island and at the ABC mine (Fig. 10 and accompanying map). The lower part of the Melville Lake Formation has a higher proportion of silt and clay beds than the upper part (Fig. 10). Tremblay (1972) estimated the silt and clay in the Melville Lake Formation to be 60 percent. At the ABC mine clay and silt constituted up 24 percent of the section (Fig. 10C); up-section at the northern adit (Fig. 10D) the section contains 2 percent silt and clay beds, 7 percent conglomerates and 91 percent fine-grained sandstone.

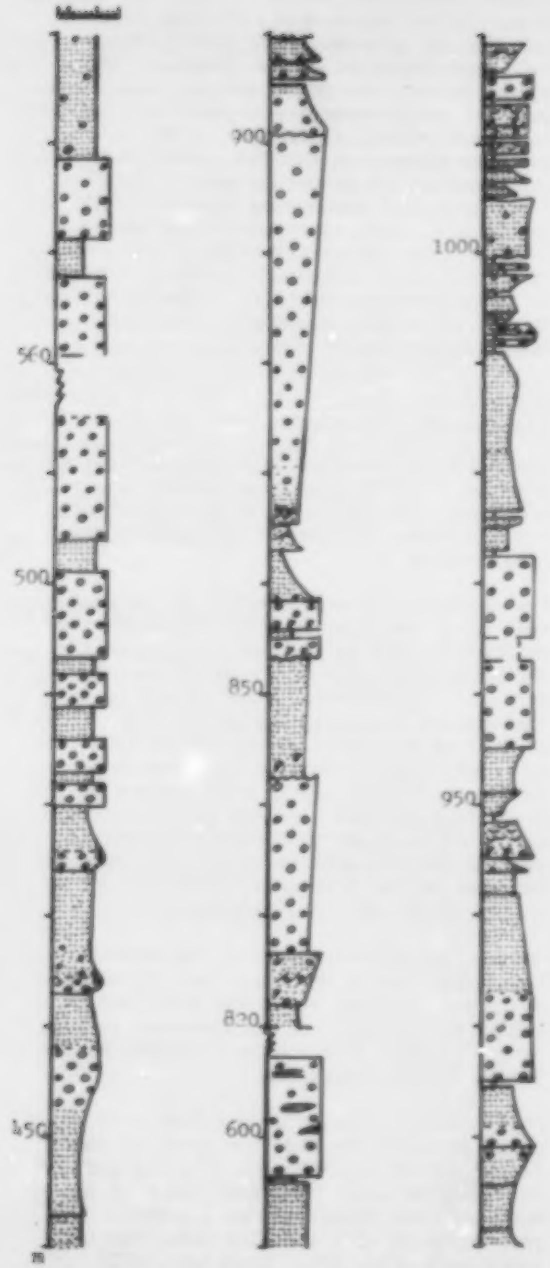

Figure 8 - Seaplane Base Formation. Continuation of section from Fig. 5 (locality 176 on accompanying map).

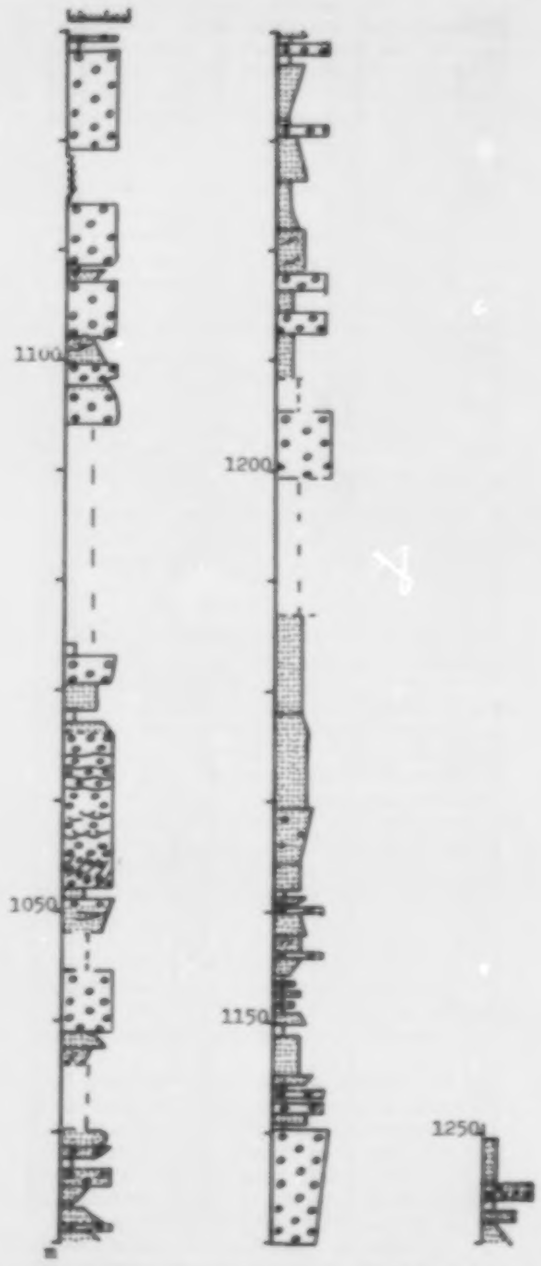

Figure 9 - Uppermost part of Seaplane Base Formation. Continuation of section from Fig. 6 (locality 5 on accompanying map).

Although there is an increase in the proportion of sand upwards through the measured sections, the sand is fine to medium grained throughout the section (Fig. 10). Individual sand units (1.5 to 3 m) fine upward, although a few upward-coarsening units do occur (Fig. 10).

The lowermost part of the Melville Lake Formation is characteristically thin bedded, less than 1.5 m for sand beds and a few centimetres for the silt and clay beds. The most common structures are ripple marks, mudcracks, sandstone dykes and mud drapes.

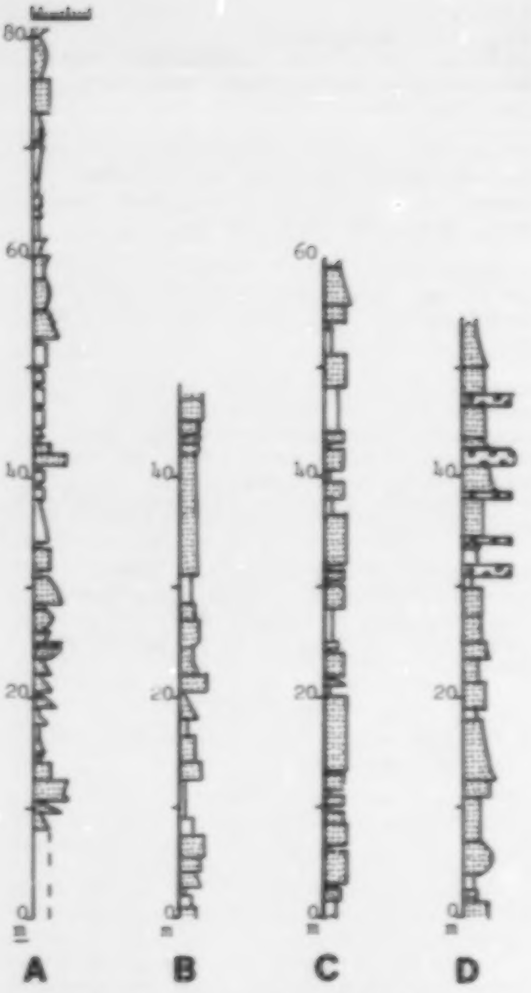

Figure 10 - Stratigraphic sections in Melville Lake Formation: (A) roadcut section (locality 183 on accompanying map); (B) Stoick Island (locality 187); (C) ABC mine (locality 82); (D) ABC mine (locality 188). Section A is stratigraphically lowest, section D is the highest.

The ripple marks are commonly symmetrical. There is some soft sediment deformation and very few intraformational clasts compared to the Seaplane Base Formation immediately below. The lower units of the Melville Lake Formation are typically chocolate brown and some of the clay beds are green or spotty green to chocolate brown; the sandstone is generally orange pink.

The middle part of the Melville Lake Formation, as it is exposed on Stoik Island and at the ABC mine (Figs. 10B and C), consists of thicker sandstone beds (up to 4 m thick) and contains fewer clay and silt beds than the lower part; the clay occurs as drapes on rippled sandstones. The most common structures are ripple marks, both symmetrical and straight crested, mudcracks, sandstone dykes and, less commonly, intraformational clasts. Along the western shoreline of Melville Lake the thin siltstones are chocolate brown and the sandstone is very coarse and pebbly.

The uppermost exposed 50 m of the Melville Lake Formation consists of upward-fining, medium- to very fine grained and well-indurated pink sandstones (Fig. 10D). The sandstone beds are thick (up to 4 m), graded and gravelly in places. Towards the top of the section, thin conglomerate beds are interbedded with fine-grained sandstones. Ripple marks are less common, as are mudcracks and sand dykes.

Stromatolites have been found in scattered boulders of a pebble conglomerate at the ABC mine adit but the original bed described by Tremblay (1972) was not traced.

Summary and Conclusions

1) A total of 4193 m of section has been measured at the 1:50 scale in the Martin Group of the Beaverlodge area.

2) The general trend from bottom to top of the Martin Group is one of decreasing grain size, which is likely a result of basin-filling accompanied by lowering of relief in the source area.

3) In the early stages of basin development, during deposition of the Beaverlodge Formation, very coarse gravels accumulated adjacent to active faults in a series of small basins. Sequences of talus, alluvial fan and stream flood deposits up to 1600 m thick accumulated in parts of the basin where subsidence was most rapid. Well-sorted sands and thin-bedded gravels were deposited on slowly subsiding blocks as the initial irregularities were blanketed by sediment. Dispersal of sediment during deposition of the Beaverlodge Formation was mainly to the southwest, south and southeast.

4) Structural instability within the basin continued during deposition of the Gillies Channel sediments, but the pattern of sedimentation seems to have been relatively simple with more or less westward and southwestward dispersal of sands and gravels in braided streams. Lavas and sills were fed by fissures through the basement and the underlying Beaverlodge Formation.

5) The transition to the Seaplane Base Formation marks a change in dispersal pattern. Thickness changes, facies variations and sedimentary structures indicate that the sediments were transported to the east and southeast. The braided streams that carried the sediments had highly fluctuating discharges and shifting channels. Introduction of coarse-grained conglomerates near the top of the sequence may indicate tectonic rejuvenation of the source area.

6) The change to deposition of the relatively fine grained sediments of the Melville Lake Formation was gradual and could have resulted from reduction in relief of the source area, or scarp retreat and increasing isolation of the gravel source. The rocks are mainly the result of deposition in ephemeral lakes. Conglomerates may represent floods from adjacent alluvial fans.

7) There are clearly visible upward trends in grain size, both fining and coarsening, on several scales from thousands of metres to a few centimetres, that are likely related to factors such as rates of subsidence and intensity of tectonic activity, scarp retreat, migration of depocentres, geologically short-term climatic fluctuations, channel migration and periodic floods. Analysis of the measured sections is continuing in an attempt to evaluate the relative importance of each of these.

References

Christie, A.M. (1953): Goldfields - Martin Lake map area, Saskatchewan; Geol. Surv. Can., Mem. 269.

Elliot, C.G. (1982): A description of the Gillies Channel Formation, Martin Group; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p31-38.

Langford, F.F. (1981): The Martin Group in the greater Beaverlodge area; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p38-43.

Macey, G. (1973): A sedimentological comparison of two Proterozoic red bed successions (the South Channel and Kazan Formations of Baker Lake, N.W.T. and the Martin Formation at Uranium City, Saskatchewan); unpubl. M.Sc. thesis, Carleton Univ., Ottawa.

Sibbald, T.I.I. and Lewry, J.F. (1980): Uranium metallogenic studies: Lodge Bay area, Lake Athabasca; in Summary of Investigations 1980, Sask. Geol. Surv., Misc. Rep. 80-4, p44-48.

Tremblay, L.P. (1972): Geology of the Beaverlodge mining area, Saskatchewan; Geol. Surv. Can., Mem. 367.

Project 8418

Geological Investigations, Pelican Narrows Vicinity

by L.O. Craig[1]

Craig, L.O. (1984): Geological investigations, Pelican Narrows vicinity; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

During the summer of 1984 a portion of the study area was mapped as a continuation of field work commenced in 1983 (Craig, 1983). Fig. 1 illustrates a lithostructural division of the study area and vicinity proposed by Macdonald (1981). The study area encompasses the northernmost part of the Hanson Lake Block, extends into the adjoining Kisseynew Domain and possibly includes rocks of the Attitti Block.

The Hanson Lake Block contains rocks which have yielded Rb-Sr isochron ages predating the Hudsonian events which created or reworked most of the Precambrian rocks exposed in Saskatchewan (Bell and Macdonald, 1982). The Sahli Gneiss, which is located in the northern part of the Hanson Lake Block, contains a granulite-grade mineral assemblage in contrast to the amphibolite-grade assemblages in adjacent areas. The Kisseynew Domain is composed of Hudsonian metasediments and intrusive rocks. The Attitti Block (Macdonald, 1981) consists of gneisses of mixed composition which have been separated from the dominantly pelitic gneisses of the Kisseynew Domain.

Study of the rocks in the northern Hanson Lake Block and their relationship to the adjacent area offers a unique opportunity to determine some of the properties of the pre-Hudsonian crust and the conditions under which this earlier crust was transformed during the Hudsonian.

Fig. 2 is a preliminary geological map of the study area. Representative structural measurements are plotted in the areas mapped during 1983 and 1984. The geology of the area south of the Sahli Gneiss and the area in the northwest corner of the map are compiled from maps by Sibbald (1978), Macdonald (1974) and Macdonald and MacQuarrie (1978).

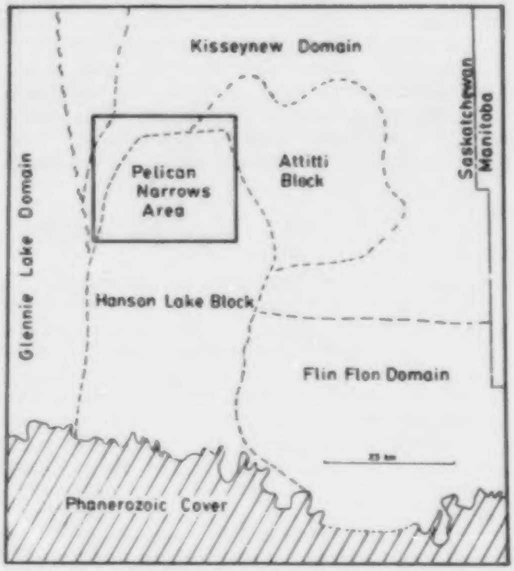

Figure 1 - Lithostructural divisions of the Pelican Narrows and adjoining areas.

Lithological Units

Sahli Gneiss (Units Sg, Sa):

The Sahli Gneiss occupies the centre of the map area. The rock is a weakly layered felsic to intermediate gneiss which retains evidence of having undergone granulite facies metamorphism. The rock is dark green when fresh and brick red to pink when weathered.

Granulitic gneiss (Sg) is found around the southern margins of Sahli Lake. The gneiss is medium grained with a granular texture and a moderately to poorly developed layering structure. The rock has a weak foliation due to the alignment of mafic mineral grains. Boudins of garnet-hornblende-pyroxene-rich rock are scattered in the more mafic gneiss layers. The rock is composed of perthitic and antiperthitic feldspars, quartz, garnet, clinopyroxene, orthopyroxene, hornblende and biotite. The hornblende and biotite grains are associated with corroded pyroxenes.

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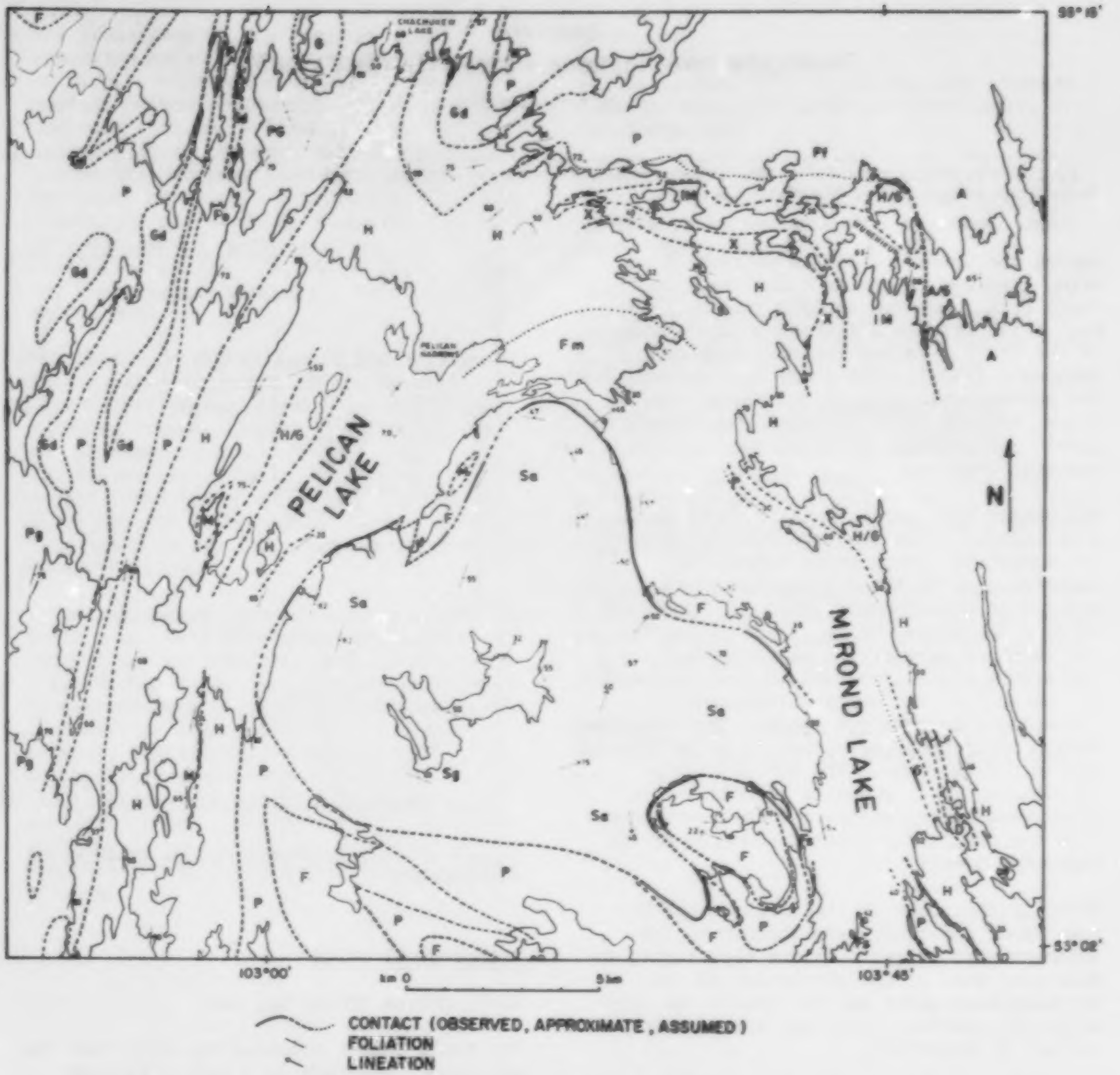

Figure 2 - Provisional geological map of the Pelican Narrows area. Sg - **Foliated or lineated gneiss:** felsic to intermediate rock with cataclastic textures and garnet-biotite-hornblende mafic mineral assemblage; locally contains corroded clinopyroxene and traces of orthopyroxene. Sa - **Granulitic gneiss:** weakly layered and foliated, granoblastic texture, with garnet, clinopyroxene, hornblende, biotite and orthopyroxene. F - **Felsic gneiss:** layered, colour index less than 10, foliated; contains hornblende and biotite. Fm - **Felsic gneiss with mafic gneiss:** as F with layers and lenses of mafic gneiss as M. Fs - **Felsic gneiss with garnetiferous mafic granulite:** as F with small bodies of granoblastic rock containing garnet, plagioclase, clinopyroxene, orthopyroxene, hornblende and biotite. P - **Pelitic gneiss:** layered and foliated gneiss with garnet, biotite, quartz, feldspar, cordierite and sillimanite. Po - **Fine-grained pelitic gneiss:** as P but finer grained; possibly retains some original compositional layering. Pf - **Pelitic gneiss with felsic layers:** as P but contains quartzose felsic and semipelitic layers. Pg - **Veined pelitic gneiss:** as P with lit-par-lit segregations, quartz-cordierite veins and granite veins. PG - **Pelitic gneiss and granite:** as P with 30 percent or less granite (G) veins and sills. M - **Mafic dykes:** composed of hornblende and plagioclase, medium to fine grained, foliated to massive. Gd - **Granodiorite gneiss:** granitoid to granoblastic, 5 to 15 percent biotite and/or hornblende, intermediate composition, medium grained, foliated. G - **Granite:** contains biotite and locally muscovite, coarse to fine grained. X - **Cataclasite:** strong cataclastic texture, intermediate to felsic, laminated, foliated, fine to medium grained. H - **Heterogeneous gneiss:** felsic, pelitic and hornblende gneisses interlayered, migmatites with granite to granodiorite leucosomes and hornblende and/or biotite gneiss melanosomes, many boudins, feldspar augen and porphyroclasts. A - **Wunehikun zone:** interfolded pelitic gneiss (P), granite (G), hornblende gneiss and granodiorite gneiss, cataclastic textures toward the centre of the zone.

In the foliated or lineated gneiss (Sa), remnants of clinopyroxene grains are common and orthopyroxene grains are rare. Pyroxenes have been replaced by hornblende and biotite. The rock has a moderate to strong mineral foliation or lineation. Cataclastic textures mask former textures. Large feldspar grains are partially recrystallized to aggregates of fine-grained feldspar, and large quartz grains are elongated and have undulose extinction or are composed of subgrains.

Felsic Gneiss (Units F, Fm, Fs):

The felsic gneisses (F) comprise a variety of lithologies with a colour index less than 10 and averaging 3 to 7. The gneisses are granular, weakly to strongly layered, and are usually foliated parallel to layering. The rock is usually light grey when fresh but weathers to pastel shades of grey, brown or pink. Plagioclase, quartz and K-feldspar together with small amounts of biotite and/or hornblende are the principal minerals.

Felsic gneiss with mafic inclusions (Fm) contains significant amounts of mafic gneiss and amphibolite. Most of the mafic layers and bodies are altered mafic dykes (unit M). Felsic gneiss with garnetiferous mafic granulite (Fs) is similar to the felsic gneisses (F) but contains small bodies of garnet-rich mafic gneiss. A similar garnet-rich mafic rock forms a much larger body along strike and immediately south of the map area. The garnetiferous mafic gneiss is composed of plagioclase, garnet, green hornblende, clinopyroxene, biotite and corroded remnants of what appears to be orthopyroxene. The pyroxenes are surrounded by hornblende grains and biotite.

Pelitic Gneiss (Units P, Po, Pf, Pg, PG):

Gneisses and schists derived from pelitic sediments (P) contain quartz, feldspars, garnet, biotite, sillimanite and cordierite. The rock is well layered and foliated. Quartzofeldspathic veins and segregations are common.

Pelitic gneiss with felsic interlayers (Pf) contains minor amounts of quartzofeldspathic to semipelitic gneiss interlayered with pelitic gneiss. Fine-grained pelitic gneiss (Po) is slightly finer grained on average than the other pelitic gneisses, and some original compositional layering appears to be preserved. The unit is less intensely deformed and apparently less metamorphosed than the majority of the pelitic gneisses. Veined pelitic gneiss (Pg) contains prominent lit-par-lit metamorphic segregations and cross-cutting quartz-cordierite or granite veins. Pelitic gneiss with granite (PG) is similar to the veined pelitic gneiss but contains up to 30 percent granite veins and sills. Gneissic layering in this subunit is commonly contorted and discontinuous.

Granite (Unit G):

This unit is coarse to fine grained, foliated to very weakly foliated, typically pink and has a colour index of 5 or less. The rock is composed of K-feldspar, quartz, plagioclase and biotite. Muscovite occurs where the granite is close to pelitic gneisses. Inclusions of country rock are common.

Cataclasite (Unit X):

The cataclasite is a medium- to fine-grained intermediate to felsic rock dominated by feldspar, quartz and biotite. The rock has a strong and very regular foliation and commonly a lamination parallel to foliation. The unit grades into grey granodiorite and migmatite (IM). To the south, the boundary of the cataclasite is placed where the regularity of foliation is lost.

Grey Granodiorite and Migmatite (Unit IM):

The grey granodiorite is medium grained, dark grey when fresh and medium grey when weathered. The rock contains both biotite and hornblende and has a colour index of approximately 10. Mineral foliation is moderately well developed and textures are granoblastic. The granodiorite contains many inclusions of country rock and hornblende-bearing gneisses which tend to have diffuse boundaries. The intrusive material and inclusions form extensive areas of migmatite.

Mafic Dykes (Unit M):

Most mafic dykes are too small to be shown at the scale of the accompanying map. The rock is black, medium to fine grained and composed of about equal amounts of plagioclase and hornblende. In some places the rock can be seen cross-cutting the country rock and can be identified as intrusive. One clear example of chilled margins and multiple intrusion was found. Most of this unit shows evidence of deformation, and contact relationships as well as initial textures have been obscured.

Granodiorite Gneiss (Unit Gd):

Granodiorite gneiss is a medium-grained rock formed from intrusive material of intermediate composition. The rock recrystallized and has a granoblastic texture. It forms concordant bodies within the pelitic gneisses (P and subunits) in the northern and western parts of the map area. In general, the rock has a prominent foliation which is approximately parallel to the foliation in the surrounding gneisses. The rock is relatively undeformed in one location along the northern boundary of the map area. Here it has a typical granitoid texture and variations in mafic content can be distinguished. Inclusions are rare and migmatites are not formed along its contacts with the pelitic gneisses.

Gneisses of the Wunehikun Zone (Unit A):

The rocks of the Wunehikun zone comprise pelitic and semipelitic gneisses similar to those in the Kisseynew Domain, granite and pegmatite, granodiorite gneiss and hornblende gneiss. The rocks are folded uprightly, progressing from moderately open at the western edge of the zone to isoclinal in the central part of the zone. Rootless folds are common where the rocks have cataclastic textures and apparent features of high strain.

Heterogeneous Gneisses (Unit H):

Heterogeneous gneiss is composed of a variety of rock types which have been combined by tectonic and metamorphic processes. The gneiss contains fragments of pelitic gneiss, felsic gneiss and amphibolite, which appear to have been supracrustal. Considerable amounts of granodiorite to granite occur as neosome between fragments of other rock types and as discrete bodies. In the most common rock type, hornblende-rich layers and boudins are suspended in a mafelsic leucosome. Textures range from granoblastic to cataclastic. Feldspar augen and porphryoclasts are common.

Structural Geology

The domain and block boundaries outlined in Fig. 1 separate the study area into distinct structural regions. The northern end of the Hanson Lake Block is dominated by a concentrically layered structure which plunges moderately to the north. The plunge and trend of minor folds and lineations in the felsic gneiss unit and the heterogeneous gneiss are approximately the same as the plunge and trend of the major structure.

The western edge of the Hanson Lake Block, which is located along the boundary between the heterogenous gneiss and pelitic gneiss, is a structural transition. To the west, units of the Kisseynew Domain trend north-northwest and dip steeply to the east; a foliation parallels the layers. To the east, heterogeneous gneiss of the Hanson Lake Block dips vertically or to the west. In the northwest corner of the Hanson Lake Block, the layers and foliation in the Kisseynew Gneisses continue northward and units of the Hanson Lake Block bend eastward. A granite dome lies in the Kisseynew metasediments immediately northwest of the northwest corner of the Hanson Lake Block, disrupting the regularity of the layers and foliation. Southward-plunging folds are associated with the southern end of the dome.

Along the northern boundary of the Hanson Lake Block, Kisseynew Gneisses and gneisses of the Hanson Lake Block are folded into a series of moderately open north-plunging folds. These folds die out northward and southward from the northern boundary.

The northeastern corner of the Hanson Lake Block is marked by the Wunehikun zone. Wunehikun folds are upright and plunge at shallow angles. The folds progress from moderately open at the western edge of the unit to isoclinal in the centre of the unit.

Metamorphism

The study area contains evidence of several metamorphic events. The Sahli Gneiss (Sg, Sa) and the garnetiferous mafic gneiss enclaves in the felsic gneiss (Fs) both contain relict two-pyroxene assemblages preserved from early granulite facies metamorphism. Elsewhere, the pelitic assemblages of the Kisseynew Domain and the Hanson Lake Block record the regional metamorphism of the Hudsonian terrain, with characteristic garnet-, sillimanite- and cordierite-bearing rocks.

References

Bell, K. and Macdonald, R. (1982): Geochronological calibration of the Precambrian Shield in Saskatchewan; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p17-22.

Craig, L.O. (1983): Pelican Narrows project; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p40-45.

Macdonald, R. (1974): Pelican Narrows (west) area: reconnaissance geological survey of 63M-2(W); in Summary of Investigations 1974, Sask. Geol. Surv., p30-37.

____________ (1975): Compilation geology, Pelican Narrows (63M) and Amisk Lake (63L); in Summary of Investigations 1975, Sask. Geol. Surv., p44-47.

____________ (1981): Compilation bedrock geology: Pelican Narrows and Amisk Lake areas; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p16-23.

Macdonald, R. and MacQuarrie, R.R. (1978): Geological re-investigation mapping, Jan Lake area; in Summary of Investigations 1978, Sask. Geol. Surv., Misc. Rep. 78-10, p16-24.

Sibbald, T.I.I. (1978): Geology of the Sandy Narrows (east) area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 170.

The Origin of Plagioclasite in the Vicinity of the Rabbit Lake Uranium Deposit

by E.C. Appleyard[1]

Appleyard, E.C. (1984): The origin of plagioclasite in the vicinity of the Rabbit Lake uranium deposit; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

'Plagioclasite' is a rock composed predominantly of albite developed extensively in association with calcareous semipelite, calc-silicate gneiss and marble in the vicinity of the Rabbit Lake uranium deposit and in many other localities within the Wollaston Domain of the northern Saskatchewan Precambrian Shield.

Description and Occurrence

In its characteristic form the rock is a texturally massive, unfoliated albite rock in which pale green diopside, bluish-green tremolitic hornblende, yellowish scapolite and sphene are generally minor and sporadic accessories. Patches in which a foliation is evident appear to be relics within the isotropically textured matrix. The plagioclase grains have a predominantly strain-free, highly polygonal texture indicating that the rock either formed subsequent to the last major episode of penetrative strain affecting the area, or underwent intensive crystalloblastic annealing at such time.

Plagioclasite forms part of the footwall complex of the Rabbit Lake deposit (Sibbald, 1976) and extends as an apparently conformable unit, intercalated with calcareous meta-arkose, calcareous semipelite, minor calc-silicate and marble, over a distance of at least 6 km northeast and southwest of the deposit (Sibbald, 1983). Other stratiform and apparently stratabound occurrences of plagioclasite occur north of Rabbit Lake in the area south and west of Ivison and Pow Bays of Wollaston Lake. Plagioclasite is also found in association with similar host rocks elsewhere in the Wollaston Lake area and widely throughout the Wollaston Domain.

Basis for Attention

These rocks have attracted attention because of the problem of their origin and because they commonly host or are found in close association with prospects of U and Mo.[2] Examples of U/Mo mineralization associated with plagioclasite include Burbidge Lake, Karpinka Lake, Don Lake, Thomas Falls (Haultain River) and Spurjack Island (Wollaston Lake). Plagioclasite and its associated host rocks comprise one of the possible sources of uranium in the Wollaston Domain.

Plagioclasite as a Metasomatite

Plagioclasite, which could also be termed "albitite", has been variously identified as scapolite gabbro, scapolite anorthosite and quartzite in earlier accounts (Knipping, 1974; Forsythe, 1977). It is herein identified as metasomatically transformed calcareous semipelite and psammite. Evidence indicative of this origin may be summarized as follows:

1) Plagioclasite units are usually stratiform and stratabound, although locally they have been mobilized and invade adjacent metasediments.

2) Unrotated relics of foliated metasediments are common in partly altered facies. In these, the massive albite-rich matrix replaces and obliterates the pre-existing foliation of the paleosome. Most large plagioclasite occurrences contain discrete conformable layers of relatively less altered metasediments.

3) Early stages of alteration are expressed as replacement veinlets of albite-hornblende-clinopyroxene developed along a crazed network of fractures within a metasedimentary host (Appleyard, 1981).

4) Contacts with marble, calc-silicate gneiss and meta-arkose are generally sharp, although tongues of alteration may emanate from plagioclasite and penetrate other units along cleavages and joints.

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[1] Department of Earth Sciences, University of Waterloo, Waterloo, Ontario. Contributed article.

[2] These pre-Helikian basement mineral occurrences are not to be confused with the Helikian unconformity-related deposits such as the Rabbit Lake deposit.

5) A continuous compositional transition from metasedimentary protolith to plagioclasite metasome has been traced by the author in the Rabbit Lake area, and other similarly continuous sequences are known from other locations. The Rabbit Lake data is reviewed below.

6) Metasediments adjacent to areas of plagioclasite are hosts to replacement patches of metasome enriched in the elements expelled during plagioclasite formation.

Semipelitic Gneiss - Plagioclasite Transition

To compare the composition of plagioclasite in various stages of development with that of the semipelitic protolith, the average compositions of incipiently albitized semipelite (Metasome I), plagioclasite with metasedimentary relics (Metasome II) and massive plagioclasite (Metasome III) have been determined (Table 1) and normalized against the average composition of calcareous semipelite (Fig. 1).

The unaltered calcareous semipelites are fine- to medium-grained foliated gneisses composed predominantly of oligoclase with variable but usually subordinate quartz and microcline. Pale bluish-green hornblende is normally more abundant than biotite. Small amounts of retrogressive epidote may be present. Apatite and tourmaline are typical minor accessories, but units also occur with more than 5 percent of these minerals as primary metamorphic constituents.

Incipient albitization is focused on a network of cracks resembling a three-dimensional pattern of syneresis fractures. These are now healed by seams of medium-coarse granoblastic albite-hornblende-clinopyroxene. More advanced stages of alteration are marked by isolated patches of metasediment engulfed in a matrix of albite, clinopyroxene, hornblende and scapolite. The final stage is a virtually

Table 1 - Average compositions of parent calcareous semipelites (Na 0.177-0.461), incipiently albitized metasediments (Metasome I; Na 0.221-0.555), plagioclasite with metasedimentary relics (Metasome II; Na 0.570-0.586) and maximum plagioclasite (Metasome III; Na 0.624-0.705) from the vicinity of the Rabbit Lake uranium deposit. Major elements are expressed in moles/10^2 cc and are computed as arithmetic averages. Trace elements are expressed in moles/m^3 and are computed as log transformed averages. n = number of samples analyzed.

	Parents	Metasome I	Metasome II	Metasome III
n	7	6	6	9
Si	2.82	2.86	2.91	2.83
Ti	0.0197	0.0170	0.0187	0.0202
Al	0.830	0.662	0.735	0.859
Fe	0.116	0.0868	0.0584	0.0670
Mg	0.289	0.503	0.350	0.305
Ca	0.130	0.347	0.136	0.136
Na	0.289	0.393	0.578	0.649
K	0.335	0.0891	0.0684	0.0737
P	0.0060	0.0058	0.0060	0.0055
C	0.0457	0.0459	0.0234	0.0352
F	0.0279	0.0133	0.0060	0.0121
Cl	0.0057	0.0017	0.0019	0.0027
Li	17.3	21.3	19.8	24.3
B	15.9	17.2	18.8	41.3
Cu	0.903	0.419	0.308	0.276
Zn	0.752	0.759	0.843	1.24
Rb	5.82	0.642	0.537	0.984
Sr	1.03	0.619	0.433	0.382
Nb	0.400	0.449	0.419	0.401
Cs	0.0877	0.0425	0.0372	0.0578
Ba	14.2	3.17	0.250	2.27
Pb	0.136	0.0964	0.098	0.103
Th	0.306	0.193	0.252	0.228
U	0.0532	0.0600	0.0603	0.0360

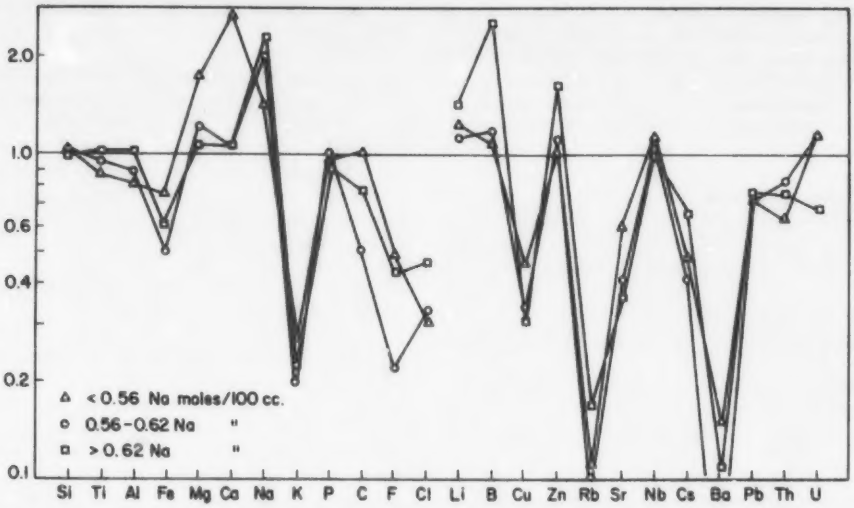

Figure 1 - Illustration of compositional variations within progressively albitized semipelitic gneisses. The three metasome groups are normalized against the average parent composition. Symbols are as follows: Metasome I, incipiently albitized metasediments (triangles); Metasome II, plagioclasite with metasedimentary relics (circles); Metasome III, maximum plagioclasite (squares).

massive albitite in which the palimpsest is preserved by a reticulate distribution of mafic minerals.

The general patterns of metasomatic fluxing are illustrated by the accompanying data. The data are standardized to a common volume so that density variations between samples do not contribute to the variance. Volume changes during alteration could not be estimated due to the degree of primary variation in the parent gneisses, and thus chemical gains and losses could not be accurately quantified. Consequently, direct comparison of the present data, without regard to possible volume changes, to estimate gains and losses may create errors of as much as ±10 to 15 percent of the values. Nevertheless, many of the chemical variations between samples greatly exceed these limits and can be regarded as qualitatively representative of the pattern of metasomatism.

The elements Si, Ti, Al, P and Nb show little relative variation and can be regarded as least mobile. Conversely, Na, Li, B, and Zn have been strongly introduced during albitization and must have been particularly enriched in the metasomatic fluids. In the sedimentary environment these elements are particularly concentrated in evaporative sequences.

Uranium has behaved variably, showing modest gains in the less altered facies and a loss in the massive plagioclasite. The primary data has a high variance which accords with the field observations of limited local mobility of U within and close to plagioclasite and calc-silicate host rocks (Appleyard, 1981).

Calcium and magnesium are strongly enriched in the incipiently altered stage and less enriched in later stages. Variances in the primary data are again high. Many plagioclasite samples show replacive diopside, and adjacent metasediments commonly contain replacement patches of diopside-hornblende-scapolite-epidote, suggesting that Ca and Mg were highly mobile elements forming a 'front' or 'wave' ahead of the main introduction of Na. During the formation of albite and the destruction of oligoclase and mafic minerals, the fluids would have changed from Na-rich to Ca-Mg-rich. Thus, in outer parts of the aureole or where second waves occurred, the metasomatism would be characterized by calc-silicate minerals.

The most dramatic elemental losses are of K, Rb, Ba, Cs and Sr, most of which correlate with the virtual eradication of all K-rich minerals from the rocks. The ultimate repository of these elements is not clear, although the hanging wall meta-arkoses in the Rabbit Lake open pit contain granitic pegmatoid patches which probably represent a portion of the expelled lithophile elements.

Iron similarly shows a substantial drop during albitization. It appears to be fixed in some calc-silicate patches and joint fillings in adjacent calc-silicate horizons.

There has been a loss of Cl and F. The destruction of halogen-enriched micas and possibly other phases presumably released Cl and F to the fluids. The lack of a suitable host phase in the plagioclasite explains their low levels in these stages. Their presence in significant quantities in the fluids is, however, attested by the halogen-enriched scapolite-bearing calc-silicate rocks which are invariably found close to plagioclasite. Some plagioclasite samples contain scapolite, and one fluorite-rich plagioclasite occurrence was examined in another part of the Wollaston Domain. Halogens were apparently rich enough in the metasomatic fluids for them to be classified as brines.

Copper shows a consistent and marked loss. This behaviour is common to other examples of Na-metasomatism (Appleyard and Williams, 1981) and serves as an example of the leaching of dispersed metals from country rocks by migrating brines. Copper-enriched fluids generated by this mechanism might produce Cu mineralization elsewhere.

Conclusions

1) Plagioclasite has been formed by the albitization of calcareous semipelitic gneiss and related Aphebian sediments of the Wollaston Group.

2) The metasomatic fluids were Na-halogen brines in early stages, but evolved to Ca-Mg brines as a consequence of progressive water/rock reactions. As a corollary of this conclusion, the plagioclasite and calc-silicate metasomes are parallel products of the same metasomatic event.

3) The parental suite of metasediments possesses relatively high levels of alkalies, halogens, Li and B, all elements which characterize evaporite sediments (Moine et al., 1981). Present evidence suggests that metasomatism is the result of the metamorphism of saliferous sediments.

4) The fluids leached significant amounts of Cu from the rocks affected by albitization. A mineralizing capacity may have been thereby acquired by the Cu-enriched fluids.

5) Uranium was locally mobile in brines, which were presumably strongly reduced. No long distance migration has, however, been demonstrated.

References

Appleyard, E.C. (1981): Calc-silicate rocks and associated metasomatites of the Wollaston Group; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p44-46.

Appleyard, E.C. and Williams, S.R. (1981): Metasomatic effects in the Faraday Metagabbro, Bancroft, Ontario, Canada; Tschermaks Min. Petr. Mitt., v28, p81-97.

Forsythe, L.H. (1977): Reconnaissance geology: the area around Middleton Lake, Geikie River area; in Summary of Investigations 1977, Sask. Geol. Surv., p5-12.

Knipping, H.D. (1974): The concepts of supergene versus hypergene emplacement of uranium at Rabbit Lake, Saskatchewan, Canada; in Formation of Uranium Ore Deposits; IAEA, Vienna, p531-549.

Moine, B., Sauvan, P. and Jarousse, J. (1981): Geochemistry of evaporite-bearing series: a tentative guide for the identification of meta-evaporites; Contrib. Mineral. Petrol., v76, p401-412.

Sibbald, T.I.I. (1976): Uranium metallogenic studies - Rabbit Lake; in Summary of Investigations 1976, Sask. Geol. Surv., p115-123.

_____________ (1983): Geology of the crystalline basement, NEA/IAEA Athabasca Test Area; in Uranium Exploration in Athabasca Basin; Geol. Surv. Can., Pap. 82-11, p1-14.

The McLennan Group Meta-arkoses, Jaysmith - Waddy Lakes Segment

by M. Nighswander[1] and J.F. Lewry[1]

Nighswander, M. and Lewry, J.F. (1984): The McLennan Group meta-arkoses, Jaysmith - Waddy Lakes segment. *in* Summary of Investigations 1984, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The northwest part of the MacLean Lake subdomain (Fig. 1) comprises a semicontinuous, northeast-trending belt of meta-arkoses and related rocks, the McLennan Group (Lewry, 1983), which is in tectonic contact with structurally overlying metavolcanic and plutonic rocks of the Central Metavolcanic belt (cf. Lewry, this volume) to the northwest. The belt has previously been mapped from its southwestern termination in the Haugen Lake synform closure, near Otter Lake, northeastwards to beyond Jaysmith Lake (Abraham and Lewry, 1981; Lewry, 1983).

This report describes the extension of the McLennan Group farther to the northeast, in the area between Jaysmith and Lower Waddy Lakes, based on M.Sc thesis fieldwork by the principal author. Preliminary mapping this summer at 1:50,000 scale has delineated major lithological elements and structural relations in this area. Major rock units encountered represent extensions of those previously mapped and described by Lewry (1983) to the southwest. The following account emphasizes differences encountered in the present area and equates presently defined units with those mapped by Kirkland (1959).

The McLennan Group

The main belt of McLennan Group meta-arkoses traced by Lewry (1983) to approximately 5 km east of Jaysmith Lake continues northeastwards as an attenuated but apparently continuous unit (see accompanying map). Two further narrow bands of meta-arkose, interdigitated with amphibolitic to calc-silicate gneisses, occur to the southeast of this in the southwestern part of the area. All three coalesce to the northeast, at which point the overall width is about 200 m. Southwest of Lindsay Lake the belt increases abruptly in width to 1000 m and the meta-arkoses here occupy the core of a northeast-plunging synform. Thereafter, the width remains relatively constant until shortly before the belt disappears into unexposed terrain in the extreme northeast of the map area, where it widens further to 1500 m. Available field and geophysical data suggest that the belt may narrow markedly again further to the northeast.

The McLennan Group comprises, in order of decreasing abundance, granitoid meta-arkose, arkosic metaquartzite, granitic neosome and arkosic metagreywacke, all essentially as described by Lewry (1983), and includes rocks previously termed "leucocratic biotite-muscovite granodiorite" and some designated "biotite gneiss" (units 5b and, in part, 1 of Kirkland, 1959). Attempts to map distinct continuous subunits within the meta-arkose assemblage were unsuccessful. Most rocks have medium- to coarse-grained granoblastic textures. Sillimanite-quartz lenses (faserkiesel) are only locally abundant, defining a fabric which locally is axial planar to isoclinal folds but elsewhere appears to predate tight minor folding. More generally, foliation is defined by weak preferred planar orientation of biotite or by more prominent muscovite or muscovite-sillimanite schistose partings in which muscovite forms 1 to 25 percent of the rock. Possible primary layering is defined locally by vague compositional banding or muscovite-rich laminae. More uniform medium-grained homogeneous 'leucogranite', lacking sillimanite, occurring in the McLennan Group may represent either massive meta-arkose or anatectic neosome. Arkosic polymictic metaconglomerates occurring north of Jaysmith Lake (Lewry, 1983) were traced eastwards for 750 m, becoming thinner and more highly deformed in this direction; clast lithologies tend to become less varied and generally more felsic to the east.

Rocks designated "unit 1B meta-arkoses" by Lewry (1983) were further examined in traverses around Jaysmith Lake. They are generally very fine grained, intensely foliated, granoblastically recrystallized, homogeneous to finely banded rocks. Many units have a siliceous appearance and may be quartz-rich; they differ markedly in character from the dominant McLennan Group granitoid meta-arkoses and may represent either intensely tectonized to mylonitic metasedimentary arkoses (J.F.L.) or possibly felsic tuffs (M.N.).

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[1] Department of Geology, University of Regina. Project funded by NSERC operating grant.

Metavolcanic Rocks of Central Metavolcanic Belt

Interlayered mixed metavolcanic and metasedimentary rocks assigned to the La Ronge Group form a narrow and locally discontinuous strip between the McLennan Group and the Brindson Lake Pluton to the northwest. In the southwest part of the area, east of Jaysmith Lake, they comprise mafic and intermediate lavas and volcaniclastics, with subordinate metagreywacke. In the vicinity of and northeast of Lindsay Lake, volcanogenic

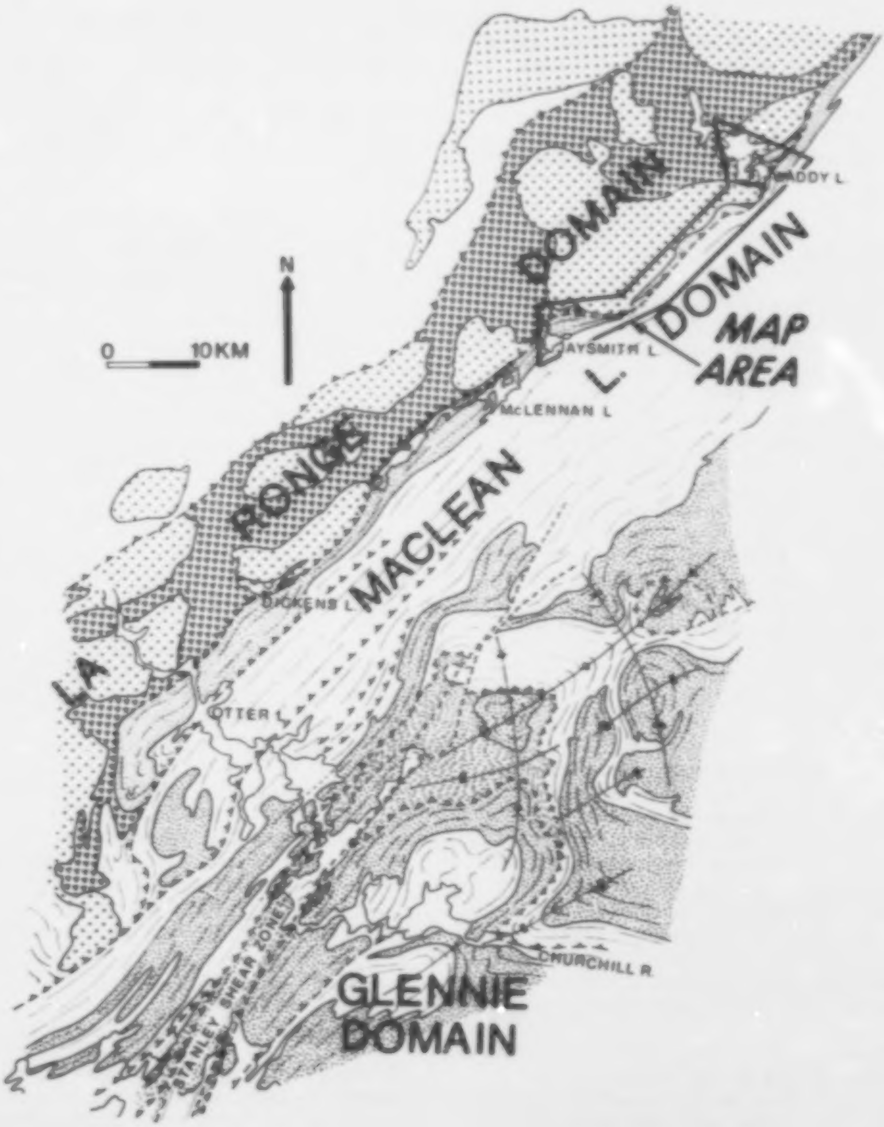
LA RONGE DOMAIN
MACLEAN
DOMAIN
L
MAP AREA
ADDY L.
AYSMITH L
McLENNAN L
DICKENS L
OTTER L
CHURCHILL R.
STANLEY SHEAR ZONE
GLENNIE DOMAIN
N
0
10KM

Figure 1 - Location of map area. General geology of the southwestern parts of the La Ronge, MacLean Lake and Glennie Domains. Explanation of symbols: open triangles - metavolcanics of the La Ronge Group; crosses - plutons in the La Ronge Domain; stipple - meta-arkoses of the McLennan Group; random ticks - undifferentiated granitic rocks and 'older gneisses' of the Glennie and MacLean Lake Domains; short dash pattern - tectonic schists of the Stanley Shear Zone and its folded extensions in the Glennie Domain; unornamented - undifferentiated supracrustal rocks of the MacLean Lake and Glennie Domains. Established and likely thrusts and shear zones are indicated by dashed lines with barbs in direction of dip. Map from Lewry, 1983.

pelitic to semipelitic greywacke siltstones (or tectonic schists?) predominate, with only minor intermediate to felsic volcaniclastics. These rocks were previously designated "hornblende and calc-silicate gneisses and granulites with interlayered biotite and biotite-garnet gneisses" (unit 3 of Kirkland, 1959). All are intensely foliated and no primary volcanic features are preserved.

Exposures of metavolcanic and plutonic rocks on Upper and Lower Waddy Lakes and inland between Lower Waddy and Redhill Lakes were examined (M.N.) as part of initial familiarization with the area. These areas are described by Harper (this volume) and not discussed here.

MacLean Lake Belt

Supracrustal rocks lying southeast of and interdigitated with the McLennan Group meta-arkoses are predominantly fine- to medium-grained psammopelitic metagreywackes with from 5 to 50 percent granitic or, locally, tonalitic neosome. Subordinate discontinuous intercalated calc-silicate gneisses occur throughout, as do amphibolite gneisses which, in the southwest, form thin mappable units. This assemblage includes mainly unit 1 as well units 3 and 3a of Kirkland (1959). All rocks have a pronounced foliation, generally parallel to mesoscopic and megascopic compositional layering, which in the metagreywackes is accentuated by parallel intrafolial neosome 'lits'.

Granitic Rocks

The Brindson Lake Pluton mostly comprises medium- to coarse-grained, grey-white biotite granodiorite and is entirely in contact with mixed metavolcanics and metasediments. As defined here, it includes "hybrid hornblende granodiorite, quartz diorite and diorite" and, in part, "hornblende granodiorite" (units 5, 4c and 4 of Kirkland, 1959). It is interfolded with the McLennan Group in this part of the belt and occupies the core of an antiform southwest of Lindsay Lake.

A narrow sheet of granite-granodiorite occurs either within or along the margin of the McLennan Group. This sheet is not connected with the Brindson Lake mass and generally comprises finer grained and somewhat less homogeneous rock. Its age relation to the Brindson Lake mass, and contact relations with the McLennan Group are presently unclear.

Structure

All supracrustal rocks in the area have a moderate to intense foliation variably obscured by granoblastic recrystallization. An indefinite to pronounced subparallel gneissic banding is common. The Brindson Lake pluton is also foliated, generally parallel or subparallel to the margin of the intrusion. The granite-granodiorite sheet to the southeast is generally poorly foliated. A 'downdip' lineation, defined by elongate biotite-rich aggregates, is seen in the Brindson Lake granodiorite and locally in the meta-arkoses. Two generations of minor folds are evident: (i) early isoclines coplanar with regional foliation and (ii) a later set of open folds.

The meta-arkoses, the southeastern parts of the Brindson Lake granodiorite and the intervening metavolcanic-metasedimentary belt lie in a major synform, and in an antiform closing southwest of Lindsay Lake. These major folds are near isoclinal, steeply overturned to the southeast and plunge to the northeast or north. The synform is cored by McLennan Group meta-arkoses and the antiform by Brindson Lake granodiorite. Foliation in the supracrustal rocks appears to be refolded around the hinges of these folds, which must therefore be at least second generation structures. Insufficient data is presently available to determine whether the foliation in the granodiorite of the antiform core is refolded or axial planar.

Structural and stratigraphic relations of the meta-arkoses and other MacLean Lake supracrustal rocks are presently uncertain. Lewry (1983) suggested that the McLennan Group southwest of Jaysmith Lake occupies a regional isoclinal synform core. If so, this structure probably predates and is refolded by the Lindsay Lake folds. The thin meta-arkose units intercalated with the metagreywackes and hornblende gneisses in the southwest may represent isoclinal fold interdigitation with the main foliation development, or primary depositional interlayering.

Future Work

Fieldwork is expected to continue in the summer of 1985, with coverage extended northeast of Waddy Lake in an effort to trace further continuation of the McLennan Group. Throughout the area, further work will be conducted at a scale of 1:20,000, involving more detailed lithological and structural mapping with particular emphasis on elucidation of boundary relationships and structural complexities identified to date.

References

Abraham, A. and Lewry, J.F. (1981): La Ronge project: I, Geology of the Otter Lake area; in Summary of Investigations, 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p26-27.

Kirkland, S.J.T. (1959): The geology of the Brabant Lake area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 33.

Lewry, J.F. (1983): Character and structural relations of the 'McLennan Group' meta-arkoses, McLennan-Jaysmith Lakes area; in Summary of Investigations, 1983, Sask. Geol. Surv., Misc. Rep. 83-4,

Notes on the Ennadai Group

by R. Macdonald

Macdonald, R. (1984): Notes on the Ennadai Group; *in* Summary of Investigations 1984, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

Several days were spent examining an assemblage of distinctive metavolcanic rocks in the Hattie Lake vicinity, on the Ennadai Project property, by arrangement with the Saskatchewan Mining Development Corporation (J.A. McNutt and D. Jiricka). This assemblage appears to comprise the 'tail end' of a regionally important belt of metavolcanics and associated metasediments extending northwards through Snowbird Lake (Taylor, 1963). Similar rocks occur in a separate basin further northeast in the Kognak River area of the Northwest Territories where they have been termed the Henik Group (Eade, 1974), and possibly also correlate with the Kaminak rocks which have yielded late Archean dates (Stockwell, 1963).

Three main rock units have been identified so far at the property: metavolcanics, metasediments and granite.

Metavolcanics

Metavolcanic rocks mainly comprise pillowed basic flows apparently on two stratigraphic levels, at least one unit of more felsic ('andesitic') pillow lavas, and mafic to mafelsic banded to more uniform tuffs. Calc-silicates are prominent in many of these rocks. At least one narrow rhyolitic unit has been identified.

The volcanic rocks lie generally on the southeast limb of a regional synform, which a majority of way-up features in pillows indicate to be a syncline. Although the metamorphic grade is probably generally above the greenshchist-amphibolite facies transition, deformation is relatively low in many of the more competent flow rocks. Strong Z-fold structures with generally northerly to northeasterly plunges are recognizable in many outcrops and at the geological map scale.

Metasediments

Generally less well exposed rocks mapped as metasediments lie northwest of the volcanics, apparently higher in sequence and at the core of the syncline. These probably include fine uniform felsic to mafelsic tuffs and volcanogenic greywacke. A prominent layer of iron formation also occurs.

Granite

Granite has been found so far lying on the eastern and southern flanks of the metavolcanic and metasedimentary outcrop, and also in a sill-like body within the supracrustal succession. Although contacts with the supracrustals have not been observed, zones of granite with large numbers of xenoliths suggest the proximity of the granite. The granite is uniformly textured and where examined has a weak to well-marked penetrative mineral foliation. Shear and mylonitic foliations of a more discrete nature are present and xenoliths are in places sheared around the margins. One narrow more or less continuous, partly sheared mafic body, possibly a dyke, is reminiscent of the sheared dykes found at Star Lake (D.J. Thomas, this volume). These observations suggest that the granite is an intermediate- to high-level pluton of syntectonic to late syntectonic age.

Regional Implication

The rocks described here are included in the Mudjatik Domain on existing geological maps of the province (e.g. Macdonald and Broughton, 1980). Features characteristic of the Mudjatik Domain, such as migmatite, anatectic supracrustals, variously remobilized basement, multiple deformation and metamorphic grades at the amphibolite-granulite facies transition (Lewry and Sibbald, 1980) are not present, however. The terrain appears instead to be less remobilized and is perhaps equivalent to the precursor meterial of the Mudjatik. Lewry and Sibbald (op. cit.) alluded to this when they suggested that the 'Hudsonian' mobile infrastructure, characteristic of the Mudjatik Domain plunges below the currently exposed crustal level in the far northeast of the province. It is proposed therefore to term this terrain the Ennadai domain. Although its presence is hinted at farther southeast near the outcrop of the Many Islands group (Munday, 1983; Lewry, 1983), its full extent remains to be determined.

Samples of the rhyolite and of massive mafic rock (flow or sill) have been dispatched for radiometric determination.

References

Eade, K.E. (1974): Geology of the Kognak River area, District of Keewatin, Northwest Territories; Geol. Surv. Can., Mem. 337.

Lewry, J.F. (1983): Geology of an area around Kohn Lake; Sask. Dep. Miner. Resour., Rep.222.

Lewry, J.F. and Sibbald, T.I.I. (1980): Thermotectonic evolution of the Churchill Province in northern Saskatchewan; Tectonophysics, v68, p45-82.

Macdonald, R. and Broughton, P. (1980): Geological map of Saskatchewan, provisional edition; Sask. Dep. Miner. Res.

Munday, R.J.C. (1973): Geology of the Dutton Lake area (east half); Sask. Dep. Miner. Resour., Rep.155

Stockwell, C.H. (1963): Second report on structural provinces, orogenies and time-classification of the Canadian Precambrian Shield; Geol. Surv. Can., Pap. 62-17, p123-137.

Taylor, F.C. (1963): Geology of the Snowbird Lake area; Geol. Surv. Can., Mem. 333.

GEOCHRONOLOGICAL INVESTIGATIONS

Project 8408

Saskatchewan Shield Rb-Sr Geochronology

by Keith Bell[1] and John Blenkinsop[1]

Bell, K. and Blenkinsop, J. (1984): Saskatchewan Shield Rb-Sr geochronology; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

New Rb-Sr whole-rock data from rocks of the Nevins Lake and Train Lake Blocks, immediately north of Lake Athabasca, have indicated events significantly older than those we have documented from elsewhere in the province.

An Archean event that we interpret as the age of granulite facies metamorphism was obtained from a hypersthene gneiss from the Nevins Lake block. Five data points yield an isochron that corresponds to an age of 2630±130 Ma (MSWD = 1.6) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7027±0.0003.

Data from a garnetiferous felsic gneiss, also part of the Nevins Lake Block, gave an age of 2315±60 Ma (MSWD = 0.2) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7061+0.0007. The five data points, however, tend to cluster into two distinct groups so that the date is based on essentially a two-point isochron. Nevertheless, the event at 2315 Ma is still considered younger than that associated with the hypersthene gneiss.

Four of six data points from a quartzofeldspathic gneiss in the Train Lake Block yield an age of 1950±125 Ma (MSWD = 0.5) and an initial $^{87}Sr/^{86}Sr$ ratio of 0.7036±0.0004. The inclusion of the two remaining samples would have the overall effect of slightly lowering the date with a consequent increase in the MSWD.

Attempts to obtain Rb-Sr whole-rock dates from a granitic intrusive sheet that lies close to the junction of the Train Lake Block and the Oldman-Bulyea transition zone proved difficult because of the restricted spread in Rb/Sr ratios (0.84 to 0.89). A model age of 1980 Ma, computed using an initial $^{87}Sr/^{86}Sr$ ratio of 0.7000, yields a maximum age for the emplacement of this body, assuming closed-system chemical behaviour. Lamprophyres that cut the Nevins Lake Block also have very uniform Rb/Sr ratios (0.14 to 0.15) and because of this it is difficult to say much about their age. In addition, a marked variation in present-day $^{87}Sr/^{86}Sr$ ratios in rocks with almost identical Rb/Sr ratios suggests either open system behaviour or variation in initial Sr isotopic composition.

The most important finding in this year's study is the indication of at least two, and perhaps three, metamorphic events ca. 2630 Ma, ca. 2315 Ma and ca. 1950 Ma(?). Of particular interest is the suggestion that there are at least two distinct metamorphic events in the Nevins Lake Block, one of which is Archean in age.

All errors have been quoted here at the two sigma level; the decay constant for $^{87}Rb = 1.42 \times 10^{-11}\ yr^{-1}$.

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[1] Ottawa-Carleton Centre for Geoscience Studies, Department of Geology, Carleton University, Ottawa. Project funded by Saskatchewan Energy and Mines.

Project 8404

Preliminary U-Pb Age Data for the Trans-Hudson Orogen in Northern Saskatchewan

by W.R. Van Schmus[1] and M.E. Bickford[1]

Bickford, M.E. and Van Schmus, W.R. (1984): Preliminary U-Pb age data for the trans-Hudson Orogen in northern Saskatchewan; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

During the summer of 1983 the authors began a program of sample collecting in the Trans-Hudson Orogen in northern Saskatchewan in collaboration with J.F. Lewry and R. Macdonald. The samples were collected for age determination, primarily by the U-Pb method on separated zircons. Bickford et al. (1983) describe the rationale for the project and give locations and descriptions of the first set of samples collected.

Preliminary Age Data

The ages reported in this section were determined in the Isotope Geochemistry Laboratory at the University of Kansas by standard methods of mass spectrometry and isotope dilution analysis. The natural constants used in age calculations are those of Steiger and Jager (1977). Most of the data given here are in preliminary form, and final ages and uncertainties will probably change slightly because 1) additional fractions of zircon suites from some samples are still to be analyzed and 2) some of the zircon suites are too discordant to give high-precision ages without further processing by air abrasion and other techniques (Krogh, 1982). Where uncertainties in the ages are given, they were calculated from the analytical data by the methods of Ludwig (1980) and are 2σ values. The locations of the samples are shown in Fig. 1 and a summary of the data is given in Table 1.

HUD-83-1 - Metarhyolite or metadacite from Laroque Lake (cf. Pearson and Froese, 1959): The sample collected, although large, did not yield many zircons; the four small fractions analyzed yielded a poorly defined chord on the concordia diagram. The age of the sample lies between 1870 and 1940 Ma but cannot be defined more precisely without more material. The sample was recollected this summer, and additional work will be done.

HUD 83-3 - Tonalite from the Davin Lake Tonalitic Gneiss Complex, south of Deception Lake (cf. Gilboy, 1982): Four zircon fractions yielded an age of 1863±12 Ma. These zircons produced an excellent fit to a chord (p=0.53) and this age will change little with further processing.

HUD 83-5 - Quartz diorite to granodiorite of the Brindson Lake pluton, north-northeast of Windrum Lake (cf. Miller, 1949): Four zircon fractions yielded a good fit to a chord (p=0.29) and an upper intercept age of 1866±11 Ma. This age should not change much with further processing.

HUD 83-6 - Gneiss of the Carroll Lake complex, south side of Carroll Lake (cf. Scott, 1981), considered as possible basement to supracrustal rocks in the Glennie Lake Domain: Four zircon fractions yield an age of 1893±35 Ma, with a probability of fit to the chord of 0.01. Further processing should reduce the uncertainty and refine the age.

HUD 83-7 - Metarhyolite with quartz and feldspar phenocrysts, about 400 m north of the north side of Palf Lake (cf. Scott, 1981): Three zircon fractions yield an excellent fit to a chord (p=0.93) and a corresponding age of 1881±6 Ma. Although other zircon fractions from this sample will be analyzed, this excellent precision will not likely be improved.

HUD 83-8 - Sahli Granite: This sample yielded abundant zircons that clearly constitute a bimodal population. Most of the zircons (about 85 percent) are relatively clear and sharply euhedral, whereas the remaining 15 percent are rounded, with shapes that suggest corrosion during metamorphism rather than rounding during sedimentary transport; the round zircons are medium to dark brown in colour. An initial analysis of fractions of this material, separated only on the basis of magnetic susceptibility, yielded a poorly-fit chord with a lower intercept at about 1900 Ma and an upper intercept at about 2575 Ma. The preliminary interpretation of these data is that the Sahli Granite is an Archean rock of primary age perhaps 2500 to 2700 Ma. It evidently underwent granulite

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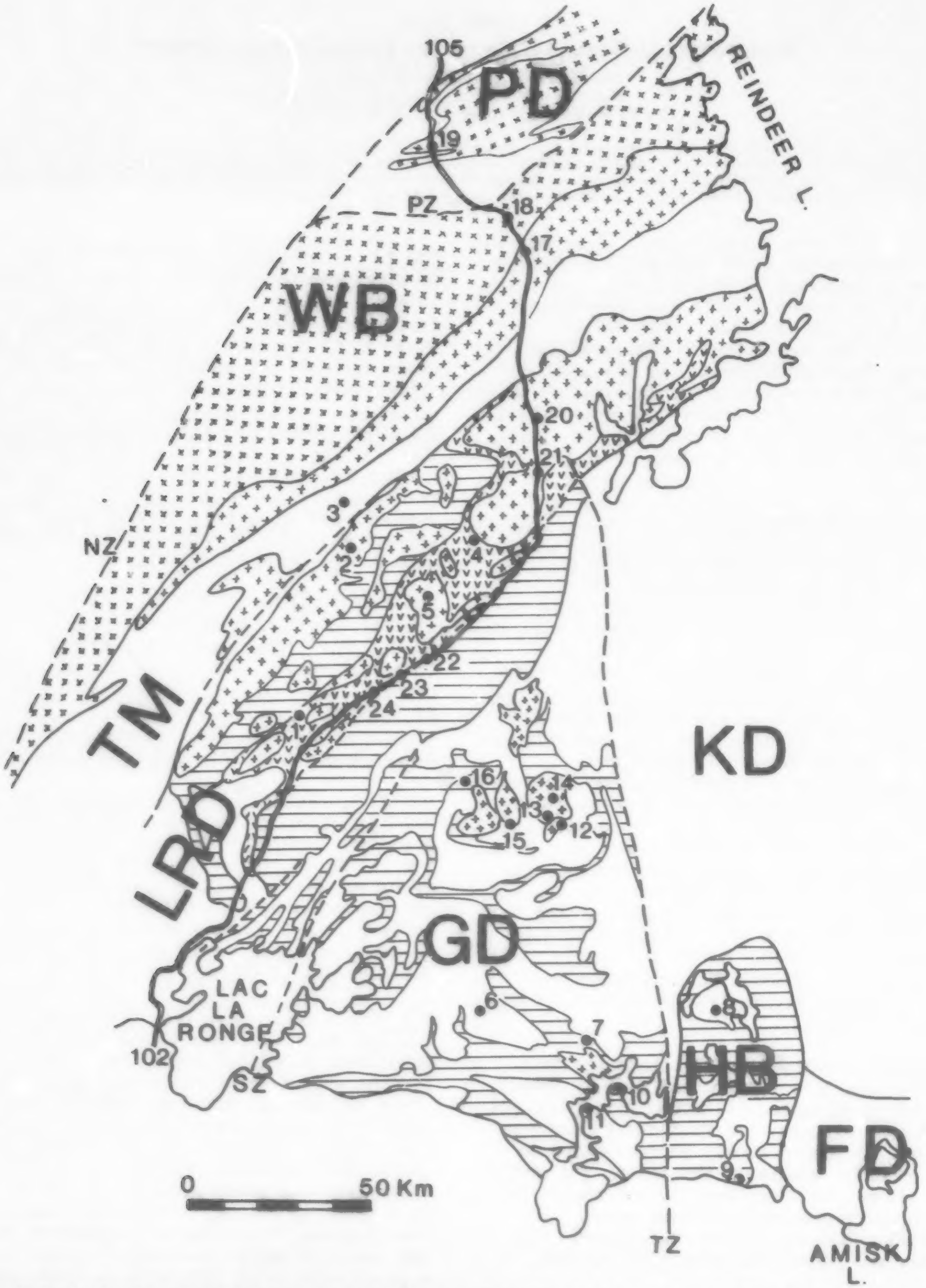
[1] Department of Geology, University of Kansas, Lawrence, Kansas 66045, U.S.A. Project provided with field support by Saskatchewan Energy and Mines (see acknowledgements).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LAC LA RONGE
8
6
7
102
SZ
HB
10
11
FD
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50 Km
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Figure 1 - Collection locations of samples discussed in text. Key: crosses, Hudsonian plutonic rocks; v-pattern, arc metavolcanics; horizontal line, undifferentiated supracrustal rocks; unornamented, undifferentiated older gneisses and plutonics of the Glennie Lake Domain and Hanson Lake Block, migmatites of the Tonalite-Migmatite Complex of the Rottenstone Domain, mafic-ultramafic rocks of the Peter Lake Domain; FD, Flin Flon Domain; HB, Hanson Lake Block; GD, Glennie Lake Domain; KD, Kisseynew Domain; LRD, La Ronge Domain; TM, Tonalite-Migmatite Complex of Rottenstone Domain; WB, Wathaman Batholith; PD, Peter Lake Domain; TZ, Tabbernor Zone; SZ, Stanley Shear Zone; NZ, Needle Falls Shear Zone; PZ, Parker Lake Shear Zone.

Table 1 - Preliminary Age Data

A) Early Volcanic Rocks of the La Ronge Belt	
HUD 83-1	1870 - 1940 Ma
HUD 83-24	1930 ± 26 Ma
HUD 83-17	1900 - 1950 Ma
B) Volcanic and Plutonic Rocks of the Glennie Lake Domain and the Hanson Lake Block	
HUD 83-6	1893 ± 35 Ma
HUD 83-7	1881 ± 6 Ma
HUD 83-9	1888 ± 12 Ma
HUD 83-16	(1863 ± 70 Ma)
C) Plutons of the La Ronge Magmatic Belt and the Wathaman Batholith	
HUD 83-3	1863 ± 12 Ma
HUD 83-5	1866 ± 11 Ma
HUD 83-18	1871 ± 13 Ma
D) Later Plutons	
HUD 83-11	1850 ± 4 Ma
HUD 83-20	1849 ± 9 Ma
E) Sahli Granite	
HUD 83-8	older fraction about 2600 ± 100 Ma younger fraction about 1900 ± 100 Ma

facies metamorphism at about 1900 Ma, and this event produced a new suite of euhedral metamorphic zircons. The chord determined by the first three analyses is therefore probably a mixing line. The two zircon populations are currently being separated by hand picking. When this work is complete we should be able to analyze magnetically separated suites of each population and obtain a better estimate for the age of each.

HUD 83-9 - Porphyritic metarhyolite from the Hanson Lake Block, southwest side of Hanson Lake (typical of the metavolcanic rocks in this area): Three zircon fractions yield an excellent fit (p=0.80) and give an upper concordia intercept age of 1888±12 Ma. Additional samples of this zircon suite will be analyzed, but the age will probably not change much.

HUD 83-11 - Tonalite from the east side of Deschambault Narrows, Glennie Lake Domain: Four zircon fractions yield an excellent fit (p=0.96) to a chord and give an upper intercept age of 1850±4 Ma. Further processing will probably not change this age.

HUD 83-16 - Biotite-hornblende-quartz-feldspar "Older Gneisses" of Lewry (1977), from the north part of Dirk's Lake, intruded by or grading into the Eyahpaise granodiorite: Bell and Macdonald (1982) reported a Rb-Sr age of 1655±55 Ma. Our samples yielded an age of 1863±70 Ma. The large uncertainty is due to the poor fit of the analytical points to a chord (p=0.03); thus, additional processing and analysis should reduce the uncertainty and refine the age significantly.

HUD 83-17 - Tonalitic gneiss along Highway 105 northeast of Davin Lake (cf. Johnston, 1973): These gneisses are part of the tonalitic gneiss complex that lies between the La Ronge Magmatic Belt proper and the Wathaman Batholith to the north. Initial analyses of five zircon fractions indicate an age between 1900 and 1950 Ma, but the fit of the analytical points to a chord is quite poor. Repeat analyses have duplicated the poorly fitting points; thus the problem is complex and may involve inherited components or overgrowths in the zircons. Air abrasion experiments are underway in the hope of generating much more concordant analytical points, thus greatly reducing the uncertainty in the age of this important sample.

HUD 83-18 - Somewhat deformed sample from the Wathaman Batholith, along Highway 105 northeast of Wathaman Lake (cf. Lewry et al., 1980): The sample yielded four zircon fractions that fit a chord with p=0.47 and indicate an age of 1871±13 Ma. This age is in good agreement with a zircon age for the Wathaman of 1865 Ma (Ray and Wanless, 1980).

HUD 83-20 - Granodiorite of the Macoun Lake pluton, along Highway 105 near the north end of Purdey Lake: Bell and Macdonald (1982) reported a Rb-Sr age of 1740±45 Ma for this body. Our sample yielded zircons which give an excellent fit to a chord (p=0.77) for four fractions and indicate an age of 1849±9 Ma. Additional processing is unlikely to change this age.

HUD 83-24 - Metarhyolite with abundant quartz and feldspar phenocrysts, along Highway 102 adjacent to McLennan Lake (cf. Morris, 1961): The sample yielded five zircon fractions which give a reasonably good fit to a chord (p=0.20) and indicate an upper intercept age of 1930±26 Ma.

Discussion

It should again be emphasized that, although the ages presented here are preliminary and may be changed with additional processing, certain patterns are becoming apparent. The ages may be arranged as follows:

A) Early volcanic rocks of the La Ronge Belt: t=1930±20 Ma. Sample HUD 83-17, tonalite gneiss northeast of Davin Lake, may be of this same general age and thus is perhaps a subvolcanic pluton. Present uncertainty in its age precludes definitive statement.

B) Volcanic and plutonic rocks of the Glennie Lake Domain and the Hanson Lake Block: t=1890±15 Ma.

C) Plutons of the La Ronge Belt and the Wathaman Batholith: t=1865±5 Ma.

D) Later plutons: t=1850±5 Ma.

The only rock studied that gives any indication of an Archean age is the Sahli Granite (HUD 83-8), which, as discussed above, may be about 2600±100 Ma and have undergone a granulite facies metamorphic event at about 1900 Ma. It is also of interest that rocks for which Rb-Sr age determinations are available have yielded zircon U-Pb ages 100 to 200 Ma older. The sole exception to this is the Wathaman Batholith, for which Bell and Macdonald (1982) reported a Rb-Sr age of 1895±45 Ma, in essential agreement with the zircon age of 1871±3 Ma reported here. The literature indicates that these results are typical of comparisons of U-Pb zircon ages with Rb-Sr ages for Proterozoic rocks, where the Rb-Sr results are commonly 5 or 6 percent lower.

The ages reported here are strikingly similar to those reported by Hoffman and Bowring (1984) for igneous events in the formation of the Wopmay Orogen, and to similar igneous events in the Penokean Orogen reported by Van Schmus (1980). We anticipate that significant comparisons will be possible as our age data are refined and that this will make possible a new tectonic synthesis of orogenic events of the Canadian Shield in the Early Proterozoic.

Expansion of the Study

During the summer of 1984 the scope of the study was significantly expanded. Three students from the University of Kansas began field study and sample collection for thesis research.

Steve Persons began collecting in the Beaverlodge area, with field supervision from R. Macdonald and T.I.I. Sibbald of the Saskatchewan Geological Survey. Steve was visited in the field by W.R. Van Schmus, who will supervise the laboratory work at the University of Kansas.

Christina Livesey collected from several plutons and one volcanic rock occurrence in the La Ronge Belt, working out of the field camp of C.T. Harper of the Saskatchewan Geological Survey. Her field work was also supervised by J.F. Lewry of the Univerity of Regina. She will be supervised at the University of Kansas by W.R. Van Schmus, who also visited her in the field.

Mike Meyer undertook field study and sample collecting at several localities to study the geochronology and petrochemistry of the Wathaman Batholith. He was supervised in the field by J.F. Lewry and M.E. Bickford; the latter will supervise his analytical work at the University of Kansas.

W.R. Van Schmus collected samples with J.F. Lewry and R. Macdonald, mostly in the La Ronge Belt, and then moved east into Manitoba where he collected Trans-Hudson Orogen samples with D. Schledewitz of the Manitoba Geological Survey. M.E. Bickford collected principally in the Glennie Lake Domain and in the tonalites that lie to the northwest of the La Ronge Belt; he worked with J.F. Lewry and R. Macdonald.

Acknowledgments

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References

Bell, K. and Macdonald, R. (1982): Geochronological calibration of the Precambrian Shield in Saskatchewan; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p17-22.

Bickford, M.E., Lewry, J.F. and Van Schmus, W.R. (1983): Zircon isotope geochronology project: U-Pb (zircon) chronology for the Hudsonian orogenic terrains in Saskatchewan; in Summary of Investigations 1983, Sask. Geol. Survey, Misc. Rep. 83-4, p34-39.

Gilboy, C.F. (1982): Geology of an area around Rottenstone and Dobbin Lakes; Sask. Miner. Resour, Rep. 193.

Hoffman, P.F. and Bowring, S.A. (1984): Short-lived 1.9 Ga continental margin and its destruction, Wopmay Orogen, northwest Canada; Geology, v12, p68-72.

Johnston, W.G.Q. (1973): 64-D-13-E: Wathaman Lake (east half); in Summary of Investigations 1973, Sask. Geol. Surv., p14-17.

Krogh, T.E. (1982): Improved accuracy of U-Pb zircon ages by the creation of more concordant systems using an air abrasion technique; Geochim. et Cosmochim. Acta, v46, p637-649.

Lewry, J.F. (1977): The geology of the Glennie Lake area; Sask. Dep. Miner. Resour., Rep. 143.

Lewry, J.F., Roberts, K. and Rees, C.J. (1980): Geology of the area around Spalding Lake; Sask. Miner. Resour., Rep. 199.

Ludwig, K.L. (1980): Calculation of uncertainties of U-Pb isotope data; Earth Planet. Sci. Lett., v46, p212-220.

Miller, M.L. (1949): The geology of the Windrum Lake area; Sask. Dep. Miner. Resour., Rep. 3.

Morris, A. (1961): The geology of the Settee Lake area (west half); Sask. Dep. Miner. Resour., Rep. 55.

Pearson, W.J. and Froese, E. (1959): The geology of the Forbes Lake area; Sask. Dep. Miner. Resour., Rep. 186.

Ray, G.E. and Wanless, R.K. (1980): The age and geological history of the Wollaston, Peter Lake and Rottenstone domains in northern Saskatchewan; Can. J. Earth Sci., v17, p333-347.

Scott, B.P. (1981): Geology of the Maynard Lake - Sandy Narrows (west) area; Sask. Miner. Resour., Rep. 186.

Steiger, R.H. and Jager, E. (1977): Subcommission on geochronology: convention on the use of decay constants in geo- and cosmo-chronology; Earth Planet. Sci. Lett., v36, p359-362.

Van Schmus, W.R. (1980): Chronology of igneous rocks associated with the Penokean Orogeny in Wisconsin; in Selected Studies of Archean Gneisses and Lower Proterozoic Rocks, southern Canadian Shield, ed. G.E. Morey and G.N. Hanson; Geol. Soc. Am., Spec. Pap. 182.

GEOCHEMICAL STUDIES

Project 8421

Geochemical Patterns for Metavolcanic Rocks of the La Ronge Domain

by B.R. Watters[1]

Watters, B.R. (1984): Geochemical patterns for metavolcanic rocks of the La Ronge Domain; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

Geochemical investigations on volcanic and related intrusive rocks from the La Ronge Domain were continued during the past year, and 178 samples collected previously were subjected to further trace element analysis. All samples have now been analyzed for major elements plus the trace elements Rb, Sr, Y, Zr, Nb, Cu, Ni, Zn, Th, Pb, Ga, Cr, V, Ba and Co (by XRF). For 32 samples the concentrations of Sc, Cs, Hf, U and REE have also been determined by INAA and isotope dilution. A Rb-Sr isotope study on suites of metalava from the Waddy Lake, Esmay Lake and Devil Lake areas was also completed (Watters and Armstrong, in press). A Sm-Nd geochronological study on the Waddy Lake suite was initiated but the results are inconclusive as yet and further work needs to be done.

The scope of this project has recently been expanded with the initiation of a lithogeochemical study funded by Saskatchewan Energy and Mines. The study is aimed at providing chemostratigraphic data from perceived gold-bearing belts in Saskatchewan. Initial studies were begun in 1984 in support of the remapping of the central La Ronge Belt in the Waddy Lake and Star Lake areas respectively (Harper and D.J. Thomas, this volume).

Major, trace element and possibly isotope analysis will be conducted in order to characterize rock units (mainly metavolcanic, but also plutonic and metasedimentary) as delineated by the field mapping, and to establish local and regional compositional variation. Interpretation of the chemical characteristics in terms of petrogenetic processes and tectonic setting will continue to constitute a significant part of the program and is expected to be even more effective with the detailed mapping and better control of sampling. Another important aspect of the new program will be to evaluate the mineralization potential of the belt (particularly for gold) and to develop models of mineralization based on field and chemical data and inferred tectonic setting.

Geochemical Patterns for Basalts

Basalts erupted in different tectonic settings generally display contrasting trace element characteristics which are amenable to analysis by geochemical discrimination techniques (e.g. Pearce and Cann, 1973; Pearce and Norry, 1979; Pearce, 1982). It has been demonstrated by Pearce (1982) that a convenient means of comparing and discriminating between basalts of different tectonic settings is to plot their compositions as geochemical patterns, using typical mid-ocean ridge basalt (MORB) as a normalizing composition. Elements used to construct such patterns are indicated in Fig. 1, their choice being based on recognizable and significant petrogenetic behaviour as well as ease of analysis (Pearce, 1982).

Broadly, the elements chosen can be divided into two groups: those which have a low ionic potential ($Z/r<3$) and are relatively mobile (Sr, K, Rb and Ba) and those with high ionic potential (Th to Cr) and relative mobility.

Since typical MORB (tholeiitic) is used as a normalizing composition, the pattern displayed by this magma type will be flat with elemental abundances close to unity. Less common alkaline MORB and transitional varieties show an enrichment in all elements from Sr to Sm (Fig. 1a).

Intraplate basalts, as typified by Hawaiian types, exhibit generally enriched patterns somewhat similar to alkaline and transitional MORB types but, nevertheless, with signficant and distinguishable differences (Pearce, 1982).

Volcanic arc basalts likewise display highly distinctive geochemical patterns characterized by a general enrichment of the alkaline elements (incompatible elements of low ionic potential) Sr, K, Rb and Ba relative to the elements Ta to Cr and to

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[1] Department of Geology, University of Regina. Project funded by NSERC grant A7418 and partly, in 1984, by Saskatchewan Energy and Mines.

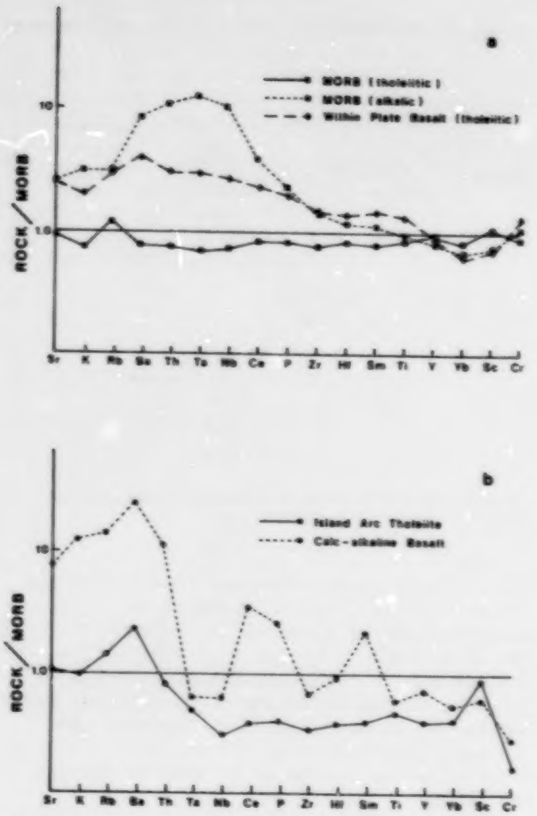

Figure 1 - Trace element distribution patterns (MORB normalized) for some typical basalts from: (a) mid-ocean ridge and within-plate settings and, (b) volcanic arc settings (from Pearce, 1982).

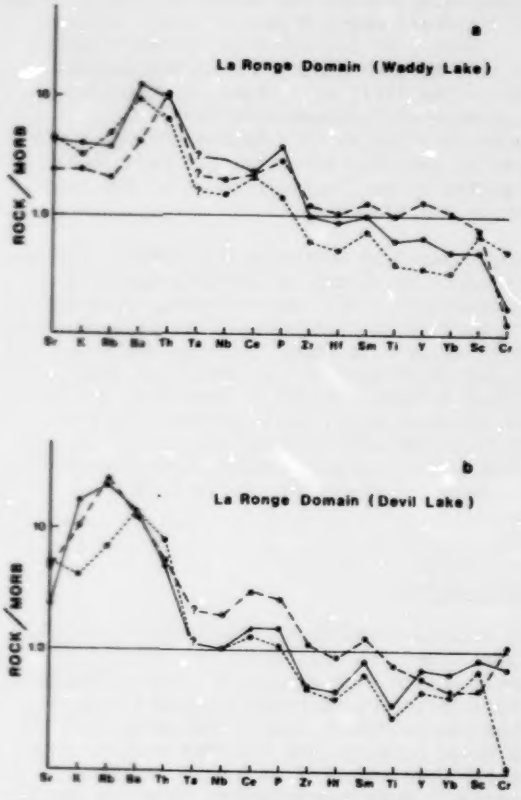

Figure 2 - Trace element distribution patterns (MORB normalized) for some typical metabasalts from the Waddy Lake (a) and Devil Lake (b) areas of the La Ronge Domain.

tholeiitic MORB. Island arc tholeiites are strongly depleted in the relatively immobile elements (high ionic potential) Th to Cr, as compared to tholeiitic MORB. Calc-alkaline basalts, while following these general patterns, are also characteristically enriched in Th, Ce, P and Sm (Fig. 1b).

Possible explanations, in terms of petrogenetic processes, for these differences in trace element distribution patterns have been discussed by Pearce (1982) and will not be repeated here.

Metabasalts of the La Ronge Domain

Trace element distribution patterns such as those discussed above have been plotted for 16 basaltic rocks from the La Ronge Domain. Representative examples from the Waddy Lake and Devil Lake (Churchill River) areas are presented in Fig. 2a and 2b respectively. Normalizing concentrations chosen for typical MORB are those suggested by Pearce (1982).

Typically, the La Ronge metabasalts display patterns resembling very closely those found in young volcanic arc basalts and are quite distinct from MORB and intraplate types. The alkaline elements Sr, K, Rb and Ba are enriched and the immobile elements (Th to Cr) have similar abundance levels to the calc-alkaline basalts, being generally depleted with respect to MORB. The elements Th, Ce, P and Sm are characteristically enriched relative to the other immobile elements. Low abundances of Ti, typical of volcanic arc rocks in general, are also evident. Ta values in Fig. 2 are estimates only, as Ta contamination was produced by crushing in a tungsten carbide vessel.

The enrichment of the alkaline elements relative to the less mobile elements such as Zr, Y, Ti and rare earth elements (REE) characteristic of volcanic arc basalts can also be demonstrated by means of a diagram of Sm/Ce against Sr/Ce as suggested by Hawkesworth (1982). The element Ce is used as a normalizing factor since it has essentially similar concentrations in basalts of different magma type.

In Fig. 3, the La Ronge metabasalts plot within the field of 'island arc basalts' (as suggested by Hawkesworth's (1982) data), being enriched in Sr (representative of the mobile, alkaline elements) and relatively depleted in Sm (representative of the less mobile REE elements).

As suggested by Pearce et al. (1981), the low abundance of Ti and Zr characteristic of volcanic arc rocks (basic-intermediate-acid) can be used to distinguish them from volcanic rocks erupted in other tectonic settings. On a plot of Ti against Zr, arc lavas fall within a field defined by generally low Ti and Zr abundances; Zr increases relative to Ti in the more evolved members of the arc association. Fig. 4 demonstrates clearly the volcanic arc character of the La Ronge metalavas.

Conclusions

If it is assumed that Proterozoic basaltic magma types from different tectonic environments were similar in compositional characteristics to those erupted recently, then the evidence clearly indicates that the La Ronge basalts (and the more evolved magma types) were emplaced in a volcanic arc setting. Such a conclusion, based on the trace element distribution patterns discussed above, lends substantial support to similar conclusions based on major and trace element and isotopic data presented elsewhere (Watters, 1981; Watters and Armstrong, in press).

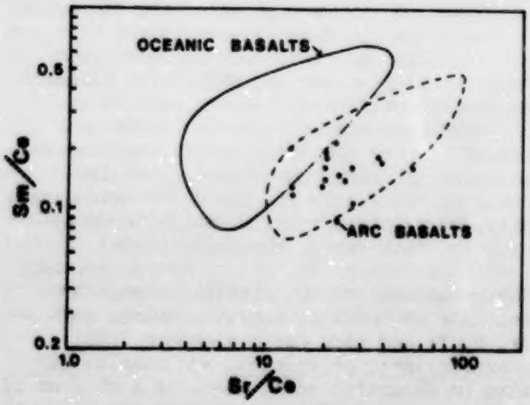

Figure 3 - Plot of metabasalts from the La Ronge Domain on a Sm/Ce vs. Sr/Ce diagram. Fields for oceanic and volcanic arc basalts have been derived from the data of Hawkesworth (1982).

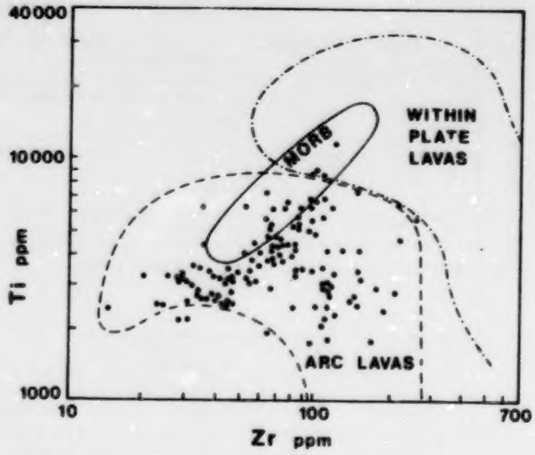

Figure 4 - Plot of Ti vs. Zr for all La Ronge Domain metalavas. Field boundaries after Pearce et al. (1981).

The La Ronge metabasalts are regarded on the basis of other lines of evidence as components of an Aphebian island arc (Watters, 1981; Lewry et al., 1981). The demonstrated correlation between geochemical patterns for basalts from young volcanic arcs and the La Ronge metabasalts suggests that the application of this particular discrimination technique to ancient basalts is viable.

References

Hawkesworth, C.J. (1982): Isotope characteristics of magmas erupted along destructive plate margins; in Andesites, ed. R.S. Thorpe, John Wiley and Sons, p549-571.

Lewry, J.F., Stauffer, M.R. and Fumerton, S. (1981): A Cordilleran type batholithic belt in the Churchill Province in northern Saskatchewan; Precambrian Res., v14, p277-313.

Pearce, J.A. (1982): Trace element characteristics of lavas from destructive plate boundaries; in Andesites, ed. R.S. Thorpe, John Wiley and Sons, p526-548.

Pearce, J.A. and Cann, J.R. (1973): Tectonic setting of basic volcanic rocks determined using trace element analyses; Earth Planet. Sci. Lett., v19, p290-300.

Pearce, J.A. and Norry, M.J. (1979): Petrogenetic implications of Ti, Zr, Y and Nb variations in volcanic rocks; Contr. Mineral. Petrol., v69, p33-47.

Pearce, J.A., Alabaster, T., Shelton, A.W. and Searle, M.P. (1981): The Oman ophiolite as a Cretaceous arc-basin complex: evidence and implications; Phil. Trans. R. Soc. A., v300, p299-317.

Watters, B.R. (1981): Geochemistry of metavolcanic rocks of the La Ronge Domain; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p34-37.

Watters, B.R. and Armstrong, R.L. (in press): Rb-Sr study of metavolcanic rocks from the La Ronge and Flin Flon Domains, northern Saskatchewan; Can. J. Earth Sci.

Projects 8415/8402

Lithogeochemistry, Flin Flon and Hanson Lake Areas

by G. R. Parslow[1]

Parslow, G.R. (1984): Lithogeochemistry, Flin Flon and Hanson Lake areas; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The east Amisk geochemical report (to be available as a Saskatchewan Energy and Mines open file) concludes that the dominant rock type present in the area is oceanic rift-related basalt; felsic volcanics and volcaniclastics are relatively rare rock types. Preliminary studies of the Annabel data suggest a dominantly volcaniclastic island arc association similar to, but not as felsic as the rocks of the west Amisk area (Watters, 1984, pers. comm.). The Hamell Lake data appear to bridge these two associations; the more southerly samples being of 'Amisk' type and the northerly samples of 'Annabel' type. There is no indication of transition between the volcanic environments, which suggests that the Annabel Lake fault zone of Byers and Dahlstrom (1954), better termed a shear zone, is a major tectonic feature that has juxtaposed two very different volcanic environments. The overall picture emerging for NTS areas 63K and 63L is one of early rifting with later extensive subduction-related volcanism. In terms of exploration potential it is interesting to note that within Saskatchewan the economic massive sulphides of Flexar, Birch Lake and Coronation are within the oceanic rift-related volcanic sequence and comparable with modern day 'black smokers'.

Reference

Byers, A.R. and Dahlstrom, C.D.A. (1954): Geology and mineral deposits of the Amisk - Wildnest Lakes area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 14.

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[1] University of Regina. Project substantially funded by Saskatchewan Energy and Mines in 1984-85.

New Developments in Geochemistry and Data Analysis at the Saskatchewan Research Council

by Michel Mellinger[1]

Mellinger, M. (1984): New developments in geochemistry and data analysis at the Saskatchewan Research Council; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

In addition to the preparation of a series of reports on graphics software for data analysis (Smith and Mellinger, 1983a, 1983b, 1984; Mellinger and Smith, 1984), work in the SRC's Geochemistry and Data Analysis Project has focused on the design of tails analysis, a new method for the study of element associations in 'anomalous' concentration ranges. The SRC has also initiated a study of gold lithogeochemistry in various geological environments in Saskatchewan (Mellinger, this volume).

Tails analysis was developed in 1981 as a means of studying element associations in mineralized and anomalous rock samples from the Maurice Bay area in the Athabasca Basin (Mellinger, 1981). It was later applied to other geochemical data and formalized. The method and applications are described in detail in Mellinger (1983).

The method studies element associations in 'anomalous' concentration ranges (i.e. in the tails of concentration frequency distributions). It allows a more extensive analysis of element associations than classical methods, which use linear correlation coefficients, because it uses robust similarity coefficients based on a binary (0,1) recoding of the data. The user is responsible for defining the parameters of the recoding procedure. Consequently, complex situations can be examined flexibly at the interpretation stage.

Tails analysis consists of the following steps:

(1) Definition of cutoff values (thresholds) above which concentrations of an element are considered to be anomalous.

(2) Precoding of the analytical data using a binary coding such that an element concentration is designated as "0" or "1" if it is lower or greater respectively than the cutoff value defined for the element. The result of this recoding is the tails table, which contains only 0's and 1's.

(3) Calculation of the element associations in tails, which are counts of co-occurrences of tail concentrations for the elements considered. For example, Cu and Zn in lake sediments may be anomalous together in most of the samples collected whereas As, another element analyzed in this case, may be anomalous when neither Cu nor Zn are anomalous. The calculated tail association between Cu and Zn in this case will be greater than that between Cu and As, and Zn and As;

(4) Interpretation of the obtained tail associations, which results in element association diagrams of various kinds.

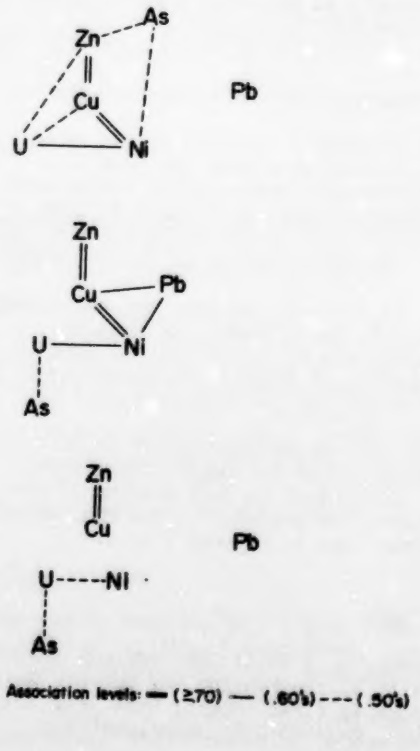

Figure 1 - Regional lake sediment survey (northern Saskatchewan): element associations obtained by tails analysis for three adjacent drainage basins. Note that the Cu-Zn cluster is invariant, as is Ni-As-U to a lesser extent.

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[1] Saskatchewan Research Council

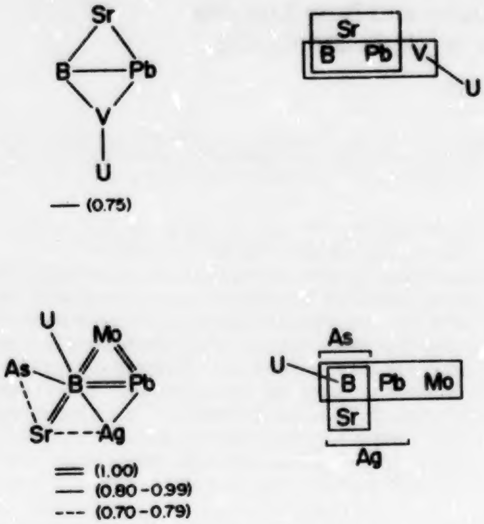

Figure 2 - Clay-altered rock samples (Maurice Bay, Saskatchewan): trace element signature obtained by tails analysis for gneiss-derived samples (top) and sandstone-derived samples (bottom). Bond-type diagrams are used at left, box-type diagrams at right. Both express the same information. Note the addition of Ag, Mo and As, and the absence of V in the sandstone-derived signature (bottom).

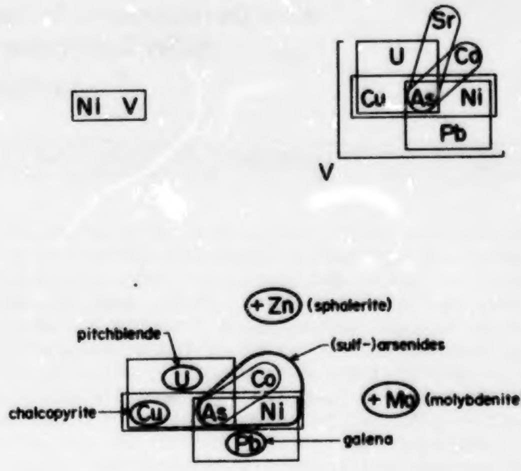

Figure 3 - Clay-altered rock samples (Midwest Lake, Saskatchewan): trace element signature obtained by tails analysis for unmineralized clay-altered diabase (top left) and a suite of mineralized clay-altered rocks (top right). Several mineralization components can be identified in the latter group when mineralogy is taken into account (bottom). Relationships were confirmed by paragenetic studies.

Tails analysis has the following advantages:

(1) It is robust; that is, it is little influenced by either the type of distribution observed for the element concentrations (a critical problem in using classical correlation coefficients) or the actual choice of cutoff values.

(2) It is flexible, as the user can interpret element associations for various selections of cutoff values, thus 'exploring' at will the nature and stability of the associations.

Examples of the application of tails analysis are explained in the report cited above, which illustrates various aspects of the interpretation procedure. The conclusions are shown here in Figures 1 to 3.

References

Mellinger, M. (1981): Geology and geochemistry of the Maurice Bay uranium deposit (Sask.): final report; Sask. Res. Counc., Publ. G-740-3-C-81 (Confidential).

____________ (1983): Tails analysis (a method for the study of element associations in "anomalous" concentration ranges): method, applications, and a computer program; Sask. Res. Counc., Publ. R-740-4-B-83 (also Sask. Res. Counc., Tech. Rep. 148).

Mellinger, M. and Smith, J.W.J. (1984): Graphics software for data analysis: I. system design; Sask. Res. Counc., Publ. R-851-3-B-84 (also Sask. Res. Counc., Tech. Rep.).

Smith, J.W.J. and Mellinger, M. (1983a): Graphics software for data analysis: III. histogram program - user's guide; Sask. Res. Counc., Publ. R-740-5-B-83 (also Sask. Res. Counc., Tech. Rep. 146).

__________________________ (1983b): Graphics software for data analysis: IV. bivariate plot program - user's guide; Sask. Res. Counc., Publ. R-740-9-B-83 (also Sask. Res. Counc., Tech. Rep. 147).

__________________________ (1984): Graphics software for data analysis: II. data transfer and data file management - user's guide; Sask. Res. Counc., Publ. R-851-2-B-84 (also Sask. Res. Counc., Tech. Rep. 156).

Project 8420

Biogeochemical Method and Surveys, Southern La Ronge Belt

by Colin E. Dunn

Dunn, C.E. (1984): Biogeochemical method and surveys, Southern La Ronge Belt; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The study area is dominated by metavolcanic and metasedimentary rocks with felsic plutons. A reconnaissance scale survey conducted in 1983 (Dunn, 1983) indicated that vegetation in the southern part of the La Ronge Gold Belt (Stanley Mission road, Lat. 55°20') had higher concentrations of gold than vegetation growing near Hwy. 102 northward to Brabant Lake (Fig. 1). It appeared that this southern area warranted more detailed investigation, and consequently further studies were conducted from June to September, 1984. Sample preparation and analysis are ongoing and analytical data have been received from about one-quarter of the 5000 samples collected. Therefore, the observations in this report are preliminary and subject to revision. All data expressed here are in ashed material, unless otherwise stated.

Objectives

Studies were designed to resolve numerous questions concerning the natural controls of gold distribution in vegetation, and to ascertain the reliability and limitations of biogeochemical surveys in defining gold-rich areas in general, and gold deposits in particular.

The prime objectives of the present survey were to determine:

1) regional patterns of gold concentrations in various plants, with particular emphasis upon species that are widespread in northern Saskatchewan and are practical to collect;
2) regional patterns of possible 'pathfinder' elements for gold in various common plants;
3) the chemical response of common plants to known gold occurrences;
4) the distribution of gold within a particular plant, in order to determine more precisely the optimum sample medium;
5) the relative gold uptake of the two common species of alder in northern Saskatchewan, Alnus crispa and Alnus rugosa;
6) the local variation of metal concentrations (i.e. changes within a given species from one plant to the next);
7) the seasonal changes in metal uptake;
8) a hierarchy of the 'usefulness' of common plant species for assisting in the exploration for gold;
9) the relative effectiveness of geochemical surveys using rock, soil, humus and vegetation in exploring for gold.

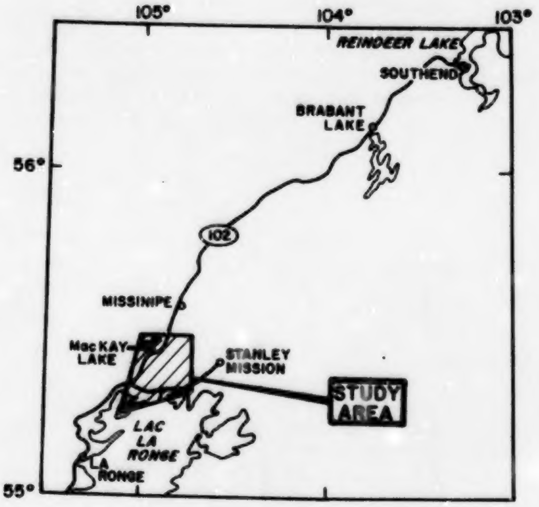

Figure 1 - Location map.

Finally, an on-going objective is to augment the data base of metal concentrations in common plant species growing over different substrates in Saskatchewan's northern forest, the ultimate aim being to establish a) background concentrations, b) the natural controls on metal concentrations, and hence c) the patterns of metal distribution that might be related to mineralization.

Sampling Program

A five-person team collected over 5000 samples of a variety of vegetation, humus and rock from approximately 1200 locations within an area of 300 km^2. The abundance of lakes, swamps and streams dictated the choice of traverses. Where possible, traverses were run normal to the northeasterly regional trend, with samples collected at 200 m intervals (Fig. 2).

Sampling was conducted during a three-week period in June, a three-week period in July/August and one week in the latter part of September. This 'time design' was chosen in order to determine seasonal changes in element uptake by the vegetation, since this is known to be a crucial factor in interpreting biogeochemical data in general.

Work conducted in previous years indicated that alder has a tendency to concentrate gold (Dunn, 1983). Balsam fir twigs also seem effective in outlining mineralization, as does the outer bark of some conifers (Dunn,

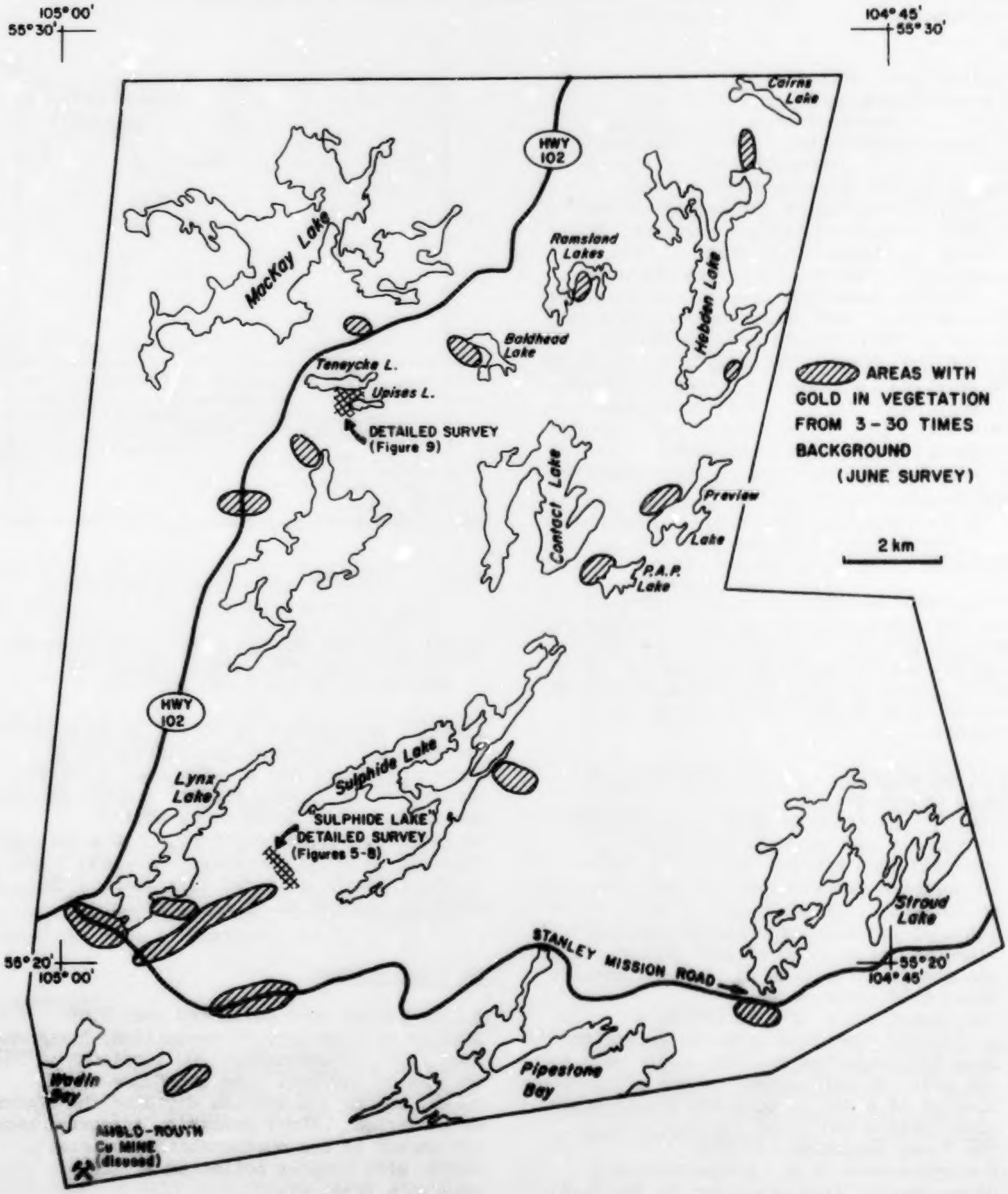
105° 00'
55° 30'
104° 45'
55° 30'
Cairns Lake
HWY 102
MacKay Lake
Ramsland Lakes
Hebden Lake
Baldhead Lake
Teneycke L.
Upises L.
DETAILED SURVEY (Figure 9)
Contact Lake
Preview Lake
P.A.P. Lake
▨ AREAS WITH GOLD IN VEGETATION FROM 3 - 30 TIMES BACKGROUND (JUNE SURVEY)
2 km
HWY 102
Sulphide Lake
Lynx Lake
SULPHIDE LAKE DETAILED SURVEY (Figures 5-8)
Stroud Lake
55° 20'
105° 00'
STANLEY MISSION ROAD
55° 20'
104° 45'
Wadin Bay
Pipestone Bay
ANGLO-ROUYN Cu MINE (disused)

Figure 2 - Limits of survey area, showing locations of gold enrichment in vegetation (June survey).

in press). Where available, alder twigs and the outer bark of spruce were collected together with a humus and rock sample for comparative chemistry. In the absence of alder, as for example in areas dominated by balsam fir or jack pine, fir twigs or the outer bark of jack pine was sampled. At selected sites a variety of other plant species and B horizon soils was obtained. A rock sample was collected where outcrop was present within a few metres of the vegetation sampling site (about 50 percent of sites).

Sample Collection, Preparation and Analytical Program

Mountain alder (Alnus crispa) is the common dryland alder in northern Saskatchewan. The speckled alder (Alnus rugosa) occurs only in wet areas, especially along stream banks. Both species were collected according to availability, with A. crispa representing about 90 percent of the samples. At a few locations where the two species occurred together, both were sampled to permit a direct comparison of their chemistry. For the alder, about 200 g of the outermost 50 cm of twig growth provided a suitable sample volume. Commonly this comprised about 12 lengths of twig. Twigs of similar age (usually about 3 years) and appearance were obtained, with note made of growth collected from older plants.

About 30 g of outer bark was scraped from black or white spruce, according to availability. Again, at the few locations where the two species were present, both were sampled to permit comparison. At selected sites, samples were taken of balsam fir twigs, needles, bark and trunk wood; black and white spruce twigs, needles and inner bark; birch twigs, leaves and bark; poplar bark; jack pine bark; labrador tea stems and leaves; leather leaf stems and leaves; and tamarack twigs and needles. In general, amounts collected were 200 g of twigs and needles/leaves, 30 g of bark and 400 g of trunk wood in order to supply adequate ashed material (0.5 to 1 g) for analysis.

A handful of humus was collected from beneath each alder sampled or, in the absence of alders, from near the trunk of a balsam fir or spruce. As the composition of the humus varied greatly, samples will be carefully examined and categorized in the laboratory prior to chemical analysis. No further comment or data on the humus will be reported here.

In the laboratory, vegetation samples were dried in a microwave oven, separated (leaves from twigs) and ashed at 475°C in a pottery kiln. Ashed samples were preweighed (0.5 to 1 g) into plastic vials and submitted for neutron activation analysis at Nuclear Activation Services Ltd., Hamilton, Ontario. Samples were analyzed initially for Au, As, Mo and Ba, with selected samples analyzed also for Sb and Zn. At least one standard and one duplicate sample were included with each batch of 20 samples submitted for analysis. In general, precision and accuracy were excellent; many duplicate samples returned identical values, and overall precision was better than ±10 percent. In the few cases where precision or accuracy was substantially greater than ±10 percent, samples were reanalyzed.

Results

Several tests were made to examine the distribution of elements within and among species.

Distribution of Elements within an Individual Plant:

The wide range in gold content of plant organs is illustrated by data obtained from various components of a jack pine (Fig. 3). Gold concentration of ashed material ranges from 14 ppb in the inner wood of the trunk to 140 ppb in the scales of the outer bark. When data are converted to a dry weight basis, this variation is further emphasized, since the range is from 40 parts per trillion(ppt) Au to 2100 ppt Au (Dunn, in press). Dissection of a black spruce tree shows a similar pattern of highest gold concentrations in the bark, but with lowest concentrations in needles (Fig. 4).

Preliminary data indicate that alders have similar gold concentrations along their twigs, although there appears to be a slight tendency for the new red growth (latest 2 years growth of Alnus crispa) to contain more gold than the older grey twigs. Molybdenum shows a strong tendency to concentrate in the new growth, whereas the converse applies for barium.

Clearly, the careful choice and collection of sample medium is imperative for meaningful intersite comparison of data.

Local Variation (20 by 20 m Test Plot):

In order to determine the local variation within a small area, a 400 m^2 site was selected within which twigs of all alder shrubs (Alnus crispa) and bark of all white spruce trees (Picea glauca) were sampled.

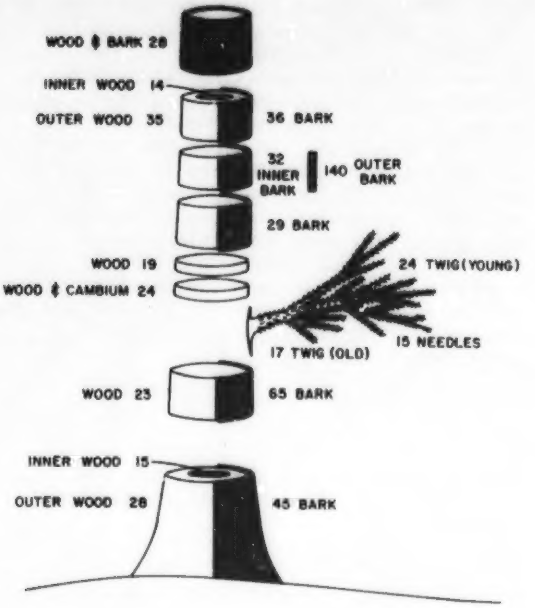
WOOD & BARK 28
INNER WOOD 14
OUTER WOOD 35
36 BARK
32 INNER BARK
140 OUTER BARK
29 BARK
WOOD 19
WOOD & CAMBIUM 24
24 TWIG (YOUNG)
15 NEEDLES
17 TWIG (OLD)
WOOD 23
65 BARK
INNER WOOD 15
OUTER WOOD 28
45 BARK

Figure 3 - Distribution of gold in ashed components of a single jack pine from the Hall deposit (Ni-Pt-Pd-Cu-Au) at Rottenstone Lake.

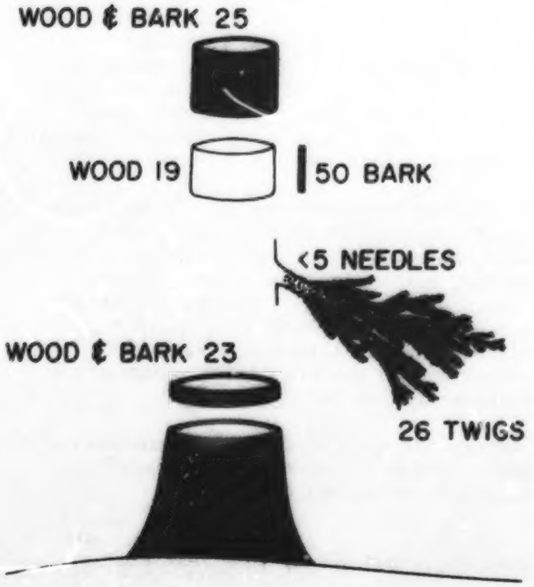
WOOD & BARK 25
WOOD 19
50 BARK
<5 NEEDLES
WOOD & BARK 23
26 TWIGS

Figure 4 - Distribution of gold in ashed components of a single black spruce from the Hall deposit (Ni-Pt-Pd-Cu-Au) at Rottenstone Lake.

The substrate comprised several metres of medium to coarse sand (auguring failed to reach bedrock). Table 1 summarizes data received from twigs of the 24 alders. Sampling was carried out in the normal way: lengths of approximately 50 cm were collected, and no more than 30 seconds was spent sampling each shrub. The variation in gold content is from beneath the detection limit of 5 ppb to 14 ppb; the arsenic range is from 0.2 to 1.7 ppm; barium ranges from 2400 to 4800 ppm; and molybdenum from 5 to 33 ppm. On the basis of these data it is considered that variations in gold content of alder twigs beneath 15 ppb are unlikely to be of significance. Similarly, arsenic concentrations below 2 ppm are probably attributable to local variations in the shrubs, rather than significant changes in soil chemistry. Barium shows a wide range in concentration, although two-thirds of the samples have values within ±10 percent of the mean concentration. Molybdenum shows the widest range in values (5 to 33 ppm) because of its propensity to concentrate in the newest growth - both new red and old grey growth were collected according to availability.

Table 1 - Local Variation in Chemistry of Ashed Alder Twigs (*Alnus crispa*) from a 20 by 20 m Test Plot

Site	Au (ppb)	As (ppm)	Ba (ppm)	Mo (ppm)
A	9	1.1	3000	13
B	<5	1.2	2800	18
C	8	1.6	3200	8
D	6	1.1	3400	13
E	14	1.6	3400	11
F	11	1.1	2400	24
G	<5	1.1	3100	7
H	<5	1.3	3300	6
I	11	1.7	2500	17
J	<5	1.2	3200	22
K	7	1.2	4000	13
L	14	0.9	3300	13
M	<5	1.0	4800	5
N	<5	0.2	2800	22
O	<5	0.2	3200	27
P	9	1.0	3500	26
Q	9	1.0	2900	10
R	5	0.6	2800	33
S	11	1.1	3300	28
T	<5	1.0	2900	24
U	10	1.1	3500	12
V	8	1.3	3300	8
W	7	1.4	2900	13
X	<5	1.0	4000	15
Mean	6.7	1.1	3230	16

Data on the chemistry of the spruce bark from this site are not available at this time.

Seasonal Changes in Plant Chemistry:

Fourteen test sites were established along the Stanley Mission road for testing seasonal changes in the chemistry of alders and spruce. These sites were visited in mid-June, early August and late September, and the same plant was sampled on each visit. Data from alder twigs and leaves collected during the first two visits are presented in Tables 2 and 3.

The seasonal contrast in the chemistry of the alder twigs is striking. From June to August the mean gold content of 18 alders from the 14 locations diminished from 28 to 10 ppb, with 16 of the alders having substantially lower gold concentrations in August. A similar pattern of element depletion during the growing season holds for both arsenic and barium: 16 of the alders yielded lower arsenic concentrations in August and 13 yielded lower barium concentrations. The pattern is less clear for molybdenum, because of its extremely heterogeneous distribution in the twigs. Even so, the mean molybdenum content is slightly lower in August. Consistent values were returned for standards submitted with the samples, precluding the possibility that the variations are the result of instrumental drift.

Table 3 - Element Concentrations in Ashed Alder Leaves Collected in June and Resampled in August, 1984

Site	Au (ppb)	
	June	August
1c	43	6
2	48	7
3a	27	18
3b	21	6
4a	25	7
4b	21	13
5	21	7
6	6	<5
7	11	8
8	8	7
9	6	5
10	10	8
11	14	7
13	13	<5
14	8	7
Mean	19	7

These results show that data from alder samples collected at different times of the year must not be compared without allowing for substantial seasonal differences.

Table 2 - Element Concentrations in Ashed Alder Twigs Collected in June and Resampled in August, 1984

Site	Au (ppb)		As (ppm)		Ba (ppm)		Mo (ppm)	
	June	Aug.	June	Aug.	June	Aug.	June	Aug.
1a	32	7	2.5	0.9	1300	900	3	8
1b	53	6	1.4	0.6	1400	700	3	2
1c	58	9	1.7	1.0	1300	900	7	4
2	34	6	1.9	1.5	700	500	2	4
3a	29	8	1.4	0.6	2200	1300	12	10
3b	35	7	1.2	1.2	2200	1700	14	7
4a	23	6	1.4	0.9	1100	900	19	22
4b	25	8	1.9	1.9	1400	1100	9	5
5	25	11	0.6	0.5	1800	1200	11	18
6	8	20	3.7	3.3	500	600	19	16
7	29	20	10.0	8.5	2000	2400	8	9
8	35	10	2.0	1.5	1700	1300	5	9
9	23	8	2.9	1.9	2000	2600	23	14
10	12	17	1.6	1.4	2400	2600	2	2
11	24	10	2.8	1.5	3300	2100	10	6
12	25	11	0.2	2.0	4300	3300	1	2
13	14	11	2.8	0.8	3100	2700	1	4
14	21	10	1.2	1.3	3400	4200	1	1
Mean	28	10	2.3	1.7	2000	1720	8.3	7.8

Girling and Peterson (1978) demonstrated an acropetal (ie. tipward migration) tendency of gold in Phacelia. By analogy it might be assumed that the gold in the alder twigs is flushed into the leaves. Tests showed no progressive increase in gold in the leaves, since in every sample the gold content of the leaves was lower in August (Table 3).

The inference to be drawn from these data is that little gold is retained in the cells of alder twigs or leaves. The gold must remain largely in solution in the sap. In June the sap is rising and high in nutrients, including any available gold. By August, the gold must have either cycled back down the xylem tissues, or possibly have aspirated through the leaves. The July/August survey period was unusually hot and dry, with daily temperatures commonly above 30ºC and no rainfall for two weeks prior to sampling the test sites. An unknown factor is the possibility of short-term changes in the alder chemistry following a heavy rainfall.

In that consistently lower gold concentrations appear to be present in the alders collected in August, the ensuing discussions of gold concentrations in alder twigs will refer only to June samples.

Differences in Element Concentrations Among Species:

Table 4 lists the common concentrations and ranges of elements in the vegetation samples collected in June. Common concentrations (which approximate the median) are presented rather than specific mean or median values, since data sets are incomplete. The data sets are considerably larger for the alder twigs and spruce bark than for the balsam fir twigs, jack pine bark and balsam fir bark. In Table 4, data from the two spruce species are combined as are data from the two alder species, since preliminary data indicate similar element concentrations in similar species.

Zinc does not exceed 2400 ppm in the samples. Jack pine and spruce show essentially the same zinc levels, whereas those in alder and balsam fir are generally lower. Similarly, arsenic and antimony levels are higher in the conifer barks, whereas molybdenum is commonly below the detection limit of 1 ppm in all media except the alder twigs. Barium concentrations are characteristically high in all media (especially the bark), and there is considerable variation in each data set. Gold concentrations are highest in alder twigs; they show similar levels in jack pine and balsam fir twigs, and are lowest in spruce and balsam fir bark.

Regional Patterns of Gold and Associated Elements in Vegetation - June Survey (Fig. 2)

During this period sampling was conducted along part of the Stanley Mission road; between Lynx and Sulphide Lakes; east of Sulphide Lake; near P.A.P. and Preview Lakes; southeast of MacKay Lake; near Ramsland Lake; and near Hebden Lake (Fig. 2). Some of these sites were selected to test the response of vegetation to known gold mineralization (ie. Sulphide and Preview Lakes), whereas others were purely exploratory traverses. Scott (this volume) outlines the geology of the area.

Alder Twigs:

Ashed alder twigs were found to contain generally less than 20 ppb Au in areas non prospective for gold mineralization. Thus, 20 ppb Au was considered background for alder twigs collected in June.

Along the Stanley Mission road, particularly the western end, gold concentrations in alders were commonly in excess of 20 ppb with a maximum value of 58 ppb. Thus, the data supported the pattern of gold enrichment in alders that was recorded the previous year (Dunn, 1983).

Some of the highest gold concentrations (up to 130 ppb) were from alders collected along the track to the Sulphide Lake zones of mineralization. Some relatively high arsenic (9 ppm) and molybdenum (73 ppm)

Table 4 - Common Concentrations and Ranges (in Parentheses) of Elements in Ashed Vegetation, June, 1984

	n[1]	Au (ppb)	As (ppm)	Sb (ppm)	Ba (ppm)	Mo (ppm)	Zn (ppm)
Alder twigs	500	20 (<5-200)	2 (<0.2- 10)	0.2 (<0.1- 1.4)	2000 (200-15,000)	10 (<1-100)	500 (90-2400)
Spruce bark (outer)[2]	300	10 (<5-140)	4 (1 -130)	0.5 (0.2-12)	4000 (300-15,000)	<1 (<1- 11)	1000 (260-1900)
Jack pine bark (outer)	30	20 (7- 39)	6 (3 - 22)	2.0 (0.8- 5)	1000 (400- 2,200)	1 (<1- 4)	1000 (190-2000)
Balsam fir bark (entire)	16	<5 (<5- 10)	1 (0.5- 16)	0.1 (<0.1- 0.2)	7000 (3400-11,000)	<1 (<1- 1)	600 (450-1000)
Balsam fir twigs	100	15 (7-140)	2 (1 - 56)	0.4 (0.1- 2.3)	4000 (1700- 7,300)	<1 (<1- 2)	600 (300-1300)

[1] approximate number of samples upon which statistics are based

[2] one sample from a trenched gold occurrence at Preview Lake yielded 2100 ppm As and 450 ppm Au

concentrations were also recorded from these shrubs.

South of Teneycke Lake several samples yielded between 50 and 200 ppb Au in the vicinity of trenched gold-copper occurrences, and farther to the southwest. Barium concentrations over 6000 ppm also occur but are displaced to the west of a zone yielding relatively high levels of Au, As and Sb.

South of Baldhead Lake gold concentrations ranged from 17 to 55 ppb, with relatively high levels of barium (up to 5000 ppm); near Ramsland and Hebden Lakes, from 5 to 56 ppb Au with slightly elevated levels of molybdenum; near Cairns Lake, from 6 to 110 ppb Au but with only 'spotty' anomalies over 30 ppb Au; to the northeast of the old Anglo-Rouyn copper mine, from 5 to 66 ppb Au with up to 5900 ppm Ba. An area of interest occurs to the east of Sulphide Lake where a series of samples yielded anomalous gold concentrations, attaining a maximum of 92 ppb Au.

No relationship between gold mineralization and zinc in alder twigs has been observed.

Spruce Outer Bark:

Gold is found to be less concentrated in the outer bark of both black spruce and white spruce than it is in alder twigs. This behaviour is in accord with the observation that gold is less strongly concentrated in spruce twigs than in those of alder (Dunn, in press). Background levels in spruce bark are below 10 ppb Au and anomalous samples tend to be isolated. Close to trenched occurrences of gold mineralization at Preview Lake, bark samples yielded up to 450 ppb Au. Two bedrock samples of phyllite from these trenches yielded 50 ppb Au, whereas material scraped from an oxidized joint surface contained 139 ppb Au. Over known gold mineralization at Sulphide Lake most samples of spruce bark contained less than 5 ppb Au, and as such failed to outline the mineralized zones. Elsewhere, the bark tends to show the same general pattern of gold concentration as alder twigs, although with lower concentrations.

Balsam Fir:

Most of the balsam fir samples were from the vicinity of the Sulphide Lake zones of mineralization. The twigs (about latest 7 years of growth) commonly yield relatively high concentrations of gold, with those from chest height usually containing more gold than twigs from the upper part of felled trees. Similarly Zn, As, Sb and Ba are more concentrated in the lower branches, with Mo rarely above detection limit in any other part of the tree examined. The bark has lower Au, As and Sb levels than the twigs, whereas Ba concentrates in the bark.

Results from Mineralized Areas

A) Sulphide Lake:

Traverses were conducted over the Studer B and C zones in the Sulphide Lake area, where gold occurs with arsenopyrite in mafic metavolcanics. Alder was found to be absent. Balsam fir twigs have considerably higher levels of gold than the white spruce bark sampled (Fig. 5). The balsam fir data are erratic, but highest concentrations are in the vicinity of gold mineralization. The source of the solitary high gold value in the spruce bark is unknown. Arsenic and antimony data (Figs. 6 and 7) for the two sample media show similar and more clearly defined relationships to mineralization, with the highest values for both species in the vicinity of known gold occurrences. Barium is concentrated in spruce bark samples on either side of the mineralized zone (Fig. 8).

B) Upises Lake:

South of Teneycke Lake there are several trenches from which gold and copper have been reported. Bedrock comprises hornblendic and calcareous gneisses. Samples of alder twigs and spruce bark showed anomalous concentrations of several elements to the east of the trenched area, southwestward from Upises Lake. The gold data from alder twigs are contoured in Fig. 9. The zone with highest gold is coincident with that of highest arsenic and antimony in both alder twigs and black spruce outer bark. Slightly elevated concentrations in the spruce bark (to 34 ppb Au) were also recorded in this zone. High barium values in alder twigs and spruce bark (up to 15,000 ppm Ba) occur farther west in an adjacent zone up to 400 m wide.

Relationship of Gold in Vegetation to Gold in Bedrock

Few data are available from this part of the study. A strong correlation between gold in vegetation and gold in bedrock chips is unlikely unless the gold is evenly disseminated throughout the bedrock. In practice, gold is commonly distributed irregularly, both on a macro and micro scale, so that a particular rock chip sample may be

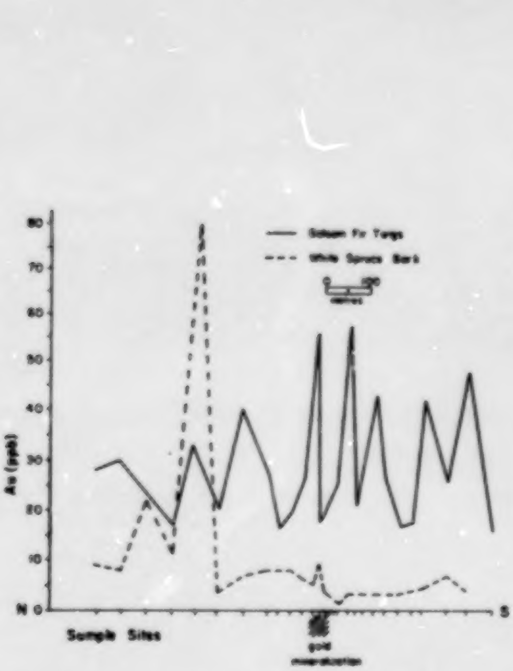

Figure 5 - Gold content of ashed white spruce bark and balsam fir twigs obtained from the Sulphide Lake zone of mineralization.

unrepresentative by virtue of the small volume sampled. By contrast, the roots of a plant may integrate the gold content of several cubic metres of soil, rock and groundwaters.

In the Sulphide Lake area, 23 rock samples yielded from less than 1 to 61 ppb Au ($\bar{x}$ = 10 ppb Au). Balsam fir twigs from the same sites had a range from 9 to 56 ppb Au ($\bar{x}$ = 23 ppb Au). The highest gold concentrations in the balsam fir were close to the highest values in the rocks. The balsam fir, however, did indicate several sites with relatively high gold levels where the rock chips returned assays of less than 1 ppb Au.

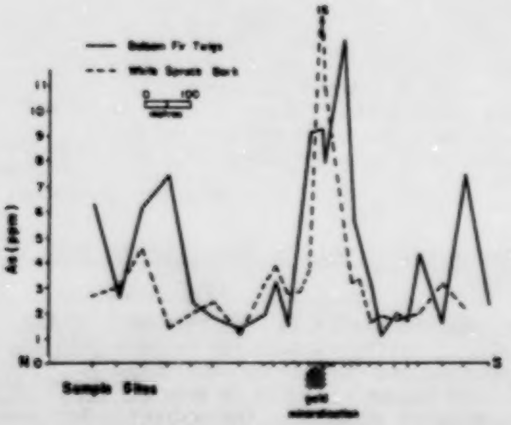

Figure 6 - Arsenic contant of ashed white spruce bark and balsam fir twigs obtained from the Sulphide Lake zone of mineralization.

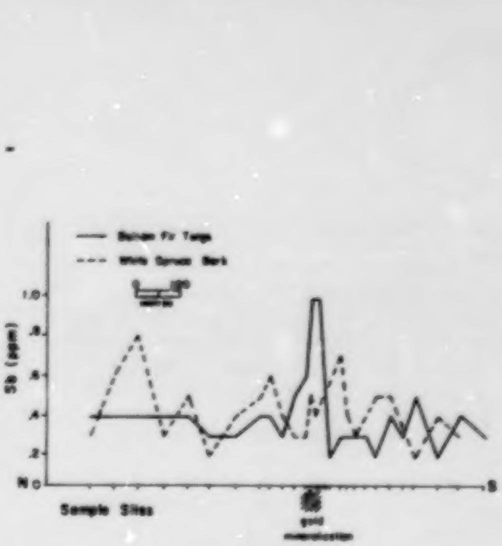

Figure 7 - Antimony content of ashed white spruce bark and balsam fir twigs obtained from the Sulphide Lake zone of mineralization.

Concluding Remarks

This preliminary compilation of the data shows biogeochemical indications of gold enrichment at many localities, some above known mineralization and others from areas where gold occurrences are unknown. Where biogeochemical anomalies occur in several sample media, gold enrichment in the bedrock is considered probable. Conversely, the absence of gold enrichment in the vegetation does not preclude the presence of mineralization; thick glacial deposits or even a metre or two of glacial clay over bedrock may be sufficient to shield the vegetation from mineralization.

The type of gold mineralization may play a significant role in the development of a biogeochemical response. For example, gold disseminated in the bedrock or associated with pyrite may give a much broader biogeochemical response than native gold that

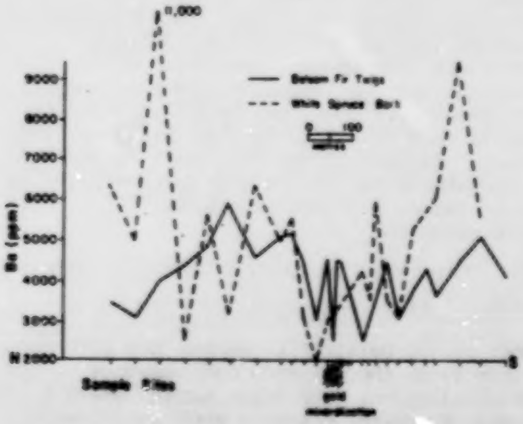

Figure 8 - Barium content of ashed white spruce bark and balsam fir twigs obtained from the Sulphide Lake zone of mineralization.

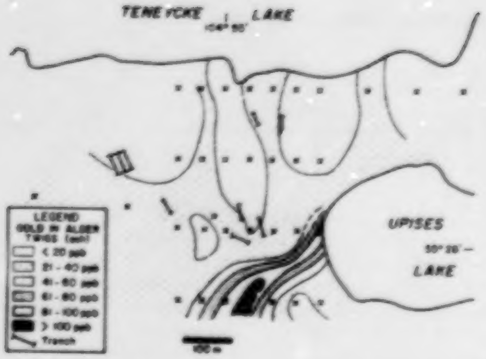

Figure 9 - Gold in ashed twigs of shrub alder (*Alnus crispa*) from the Teneycke/Upises Lakes area.

occurs as discrete grains in quartz veins. This is because the myriad of rootlets which feed each plant are more likely to intercept disseminated gold than they are to penetrate a quartz vein containing small gold particles. Furthermore, gold with pyrite or intimately associated with, for example, fine-grained volcanic rocks is more chemically reactive and accessible to plant roots than gold in quartz veins. Thus, the geological framework of an area and thence the nature of possible mineralization should be considered prior to establishing a biogeochemical sampling program and the suite of elements to be sought. It may be advantageous to include additional trace metals in an analytical program of the vegetation, since pathfinders (e.g. As, Sb, Te, Ba, Mo or Hg) may be useful in outlining potential drill targets, or help in defining areas worthy of closer investigation. By assaying the vegetation for gold alone, only mineralization close to the surface may be detected; whereas by analyzing the samples for additional trace elements, broader haloes associated with gold may be evident. Preliminary data from this study indicate that useful information can be obtained from examination of As and Sb distributions, and to a lesser degree patterns of Ba and Mo may be of value. The main value of these data is for 'stacking' geochemical anomalies which may relate to the presence of gold mineralization.

Acknowledgements

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References

Dunn, C.E. (1983): Biogeochemical investigations in northern Saskatchewan: preliminary data on tungsten, gold, platinum, rare-earths and uranium; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p106-122.

_________ (in press): Biogeochemistry as an aid to exploration for gold, platinum and palladium in the northern forests of Saskatchewan, Canada; J. Geochem. Explor.

Girling, C.A. and Peterson, P.J. (1978): Uptake, transport and localization of gold in plants; Trace Substances in Environmental Health, v12, p105-108.

Project 8420

Gold Lithogeochemistry, Sulphide Lake Area

by B.P. Scott

Scott, B.P. (1984): Gold lithogeochemistry, Sulphide Lake area; *in* Summary of Investigations 1984, Saskatchewan Geological Survey, Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

A multimedia sampling program was started in 1984, with bedrock, B horizon soil, A_1 humus soil, spruce bark, alder and Canada balsam fir being collected to determine optimum media for gold prospecting (see Dunn, this volume; Sibbald and Buller, this volume). Most samples were taken across mineral showings and at contacts between granite and metasedimentary or metavolcanic rock. Several traverse lines were made on a reconnaissance basis at a spacing of one kilometre or greater.

This report summarizes the results of a lithogeochemical study in the Sulphide Lake area supporting this multimedia program. The program is similar to one at the Pinson mine and Preble prospect in southeastern Humboldt County, Nevada, in which iron oxide fracture coatings were found to be markedly enriched in Au, As, Sb and Hg relative to adjacent rock samples (Carpenter et al., 1984). This method is potentially valuable in the search for disseminated gold deposits in northern Saskatchewan.

The Sulphide Lake area occupies the central part of the Stanley (west half) area (NTS 73-P-7-W), located approximately 30 km northeast of the town of La Ronge.

General Geology

Pelitic, semipelitic and basic to intermediate metavolcanic rocks have been intruded by a succession of mafic diorite to granite.

The area has undergone amphibolite facies metamorphism, with the local development of garnet. Visible muscovite occurs in pelitic and psammitic rocks, locally giving rise to a phyllitic sheen along foliation planes. Much alteration of biotite and hornblende to chlorite has occurred. Light yellow to light pink to white calcite occurs in semiconformable quartz-calcite veins. Rare tourmaline occurs at Ramsland Lake. Disseminated pyrite, chalcopyrite, arsenopyrite, sphalerite and graphite are common in pelitic and metavolcanic rock. Visible gold is very rarely encountered.

The Sulphide Lake low-grade gold mineralization lies within a broad northeast-trending complex belt of pelite and light grey metatuff. Calcite-rich pelites occur especially near the eastern boundary of the belt. The dominant foliation (S_1) trends northeast, with dips from vertical to steep to the northwest.

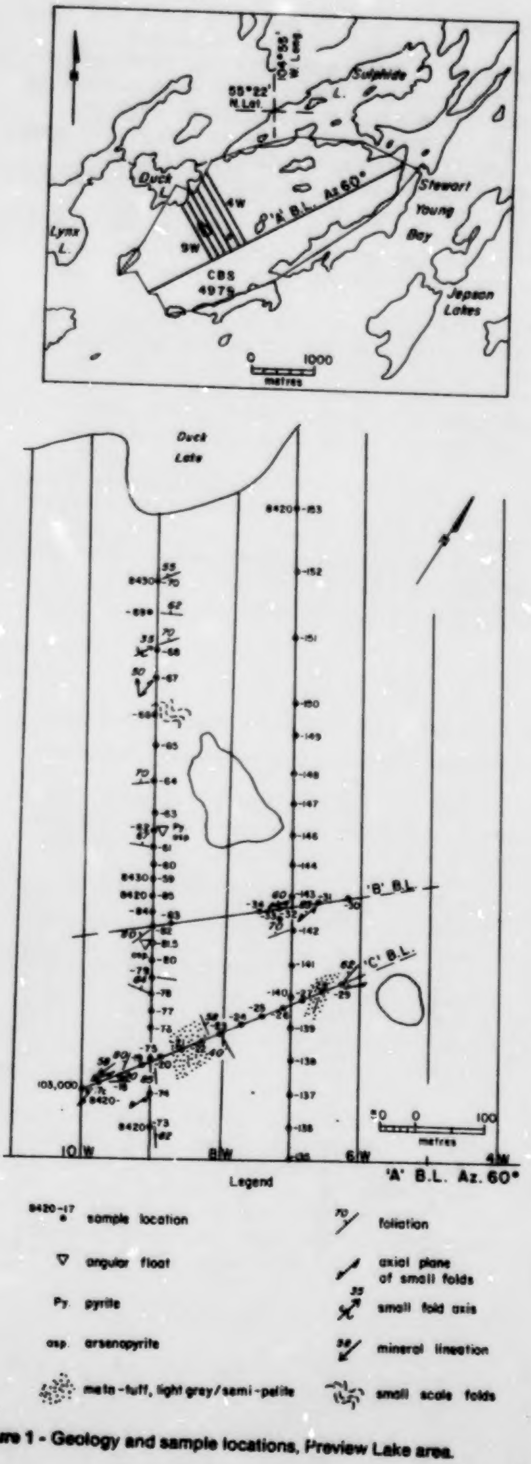
Small-scale folds trending northerly are locally well-developed in pelitic rocks. The plunge of these was not determined. An older set of small isoclinal folds, probably F_1, is oriented with axial planes subparallel to the S_1 foliation. These folds plunge to the northeast and southwest at shallow to moderate angles.

Economic Geology

The area contains numerous gossaned showings, with disseminated pyrite, pyrrhotite, chalcopyrite, arsenopyrite, sphalerite and graphite occurring in pelitic and metavolcanic rocks. Free gold is present in a few showings, but most gold values occur in sulphide-bearing rock. Trenching and shallow diamond-drilling have been carried out at MacKay Lake, Ramsland Lake, Teneycke Lake, Preview Lake and Sulphide Lake.

Ore zones at the former Anglo-Rouyn mine contain the assemblage quartz-chalcopyrite-pyrrhotite-pyrite, and plunge to the southwest at shallow angles. The host rock is a felsic gneiss, with the hornblende:biotite ratio increasing towards the ore. Quartzite occurs locally. The presence of sporadic high values of Pb, Zn, Ni and Mo in the ore may indicate rare galena, sphalerite, nickeliferous pyrrhotite and molybdenite. Free gold occurs locally. Silver mineralization was not observed, although silver values occur in ore concentrates.

A gold showing on the north-central shore of Preview Lake was extensively trenched, drilled and explored by an adit (Fig. 1). A gold brick was produced in 1946 by Preview Mines Ltd., but high-grading was subsequently discontinued because of high production costs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'C' B.L.
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6W
4W
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8420-17 sample location
angular float
Py pyrite
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meta-tuff, light grey/semi-pelite
foliation
axial plane of small folds
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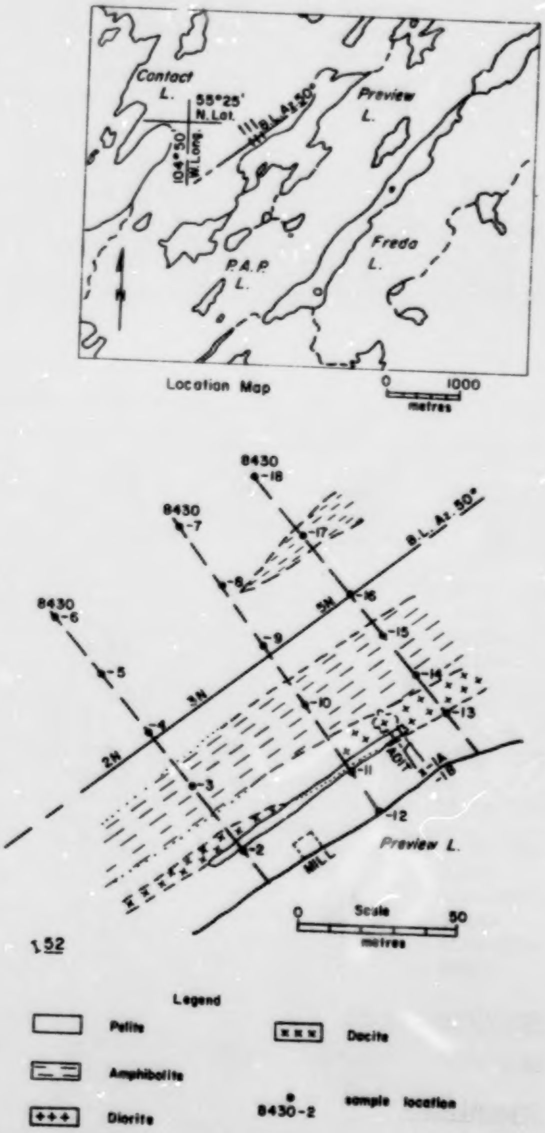
mineral lineation
small scale folds

Figure 1 - Geology and sample locations, Preview Lake area.

(Forsythe, 1971). The coarse, free-milling gold occurs in boudinaged quartz veins, within intercalated pelite and grey to green-grey intermediate to basic metavolcanics. These rocks are intruded by diorite sills.

Gold mineralization was found by V. Studer in 1937 at Sulphide Lake. The present study is concerned with an arsenopyrite-bearing zone with anomalous gold values, parallel to the 'B' baseline (Fig. 2). Host rocks are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8430-2 sample location

Figure 2 - Geology and sample locations, Sulphide Lake property. Host rocks are mainly pelite.

fine-grained pelites, with local horizons of fragmental and tuffaceous material, intruded by semiconformable veins of quartz and calcite.

Geochemistry

Sample Preparation and Analysis:

Iron oxide-rich fracture coatings were obtained from bedrock samples by placing the samples in a vise and removing fracture coatings by means of a variable-speed drill fitted with a conical tungsten carbide attachment. Nineteen one-gram samples of powder were analyzed by Barringer Magenta Ltd. for Au, Ag, As, Cd, Bi, Hg, Sb, Se and Te (Table 1).

Forty-six rock chips were analyzed by the Saskatchewan Research Council for Al_2O_3, Fe_2O_3, CaO, MgO, K_2O, Na_2O, Ni, Pb, Au, Mo, P_2O_5, Zn, Cd, Co, MnO, Cr, V, Be, Cu, TiO_2, Zr, Y, La, Th, Sr and Ba (Table 2).

Results:

Preliminary results confirm the findings of Carpenter et al. (1984), that iron oxide-rich fractures are higher in Au than the rock chips. Samples within the arsenopyritic zone in argillite, near the 'B' baseline at Sulphide Lake (Fig. 2), contain anomalous Au, with high values in As, Bi, Hg, Sb and, in one sample, Te (Table 1). Similar results were found at Preview Lake, although high values were somewhat erratic (Fig. 1).

The whole-rock analyses of the Sulphide Lake rocks indicate anomalous Au accompanied by high Fe, Ca and Co values (Table 2). The 103,000 ppb Au value is from a sulphide-bearing boudinaged quartz vein. The local background is from 1 to 15 ppb.

Samples from Heyer Bay (MacKay Lake) and east of Stewart Young Bay (Sulphide Lake) yield values of 70 and 42 ppb Au and less than 0.2 and 0.6 ppm Ag, respectively. Trenching has been carried out in these areas.

Table 1 - Oxide Fracture Coating Analyses, Sulphide Lake Area, by Barringer Magenta Ltd.

Sample No.	Au ppb	Ag ppm	As ppm	Cd ppm	Bi ppm	Hg ppb	Sb ppm	Se ppm	Te ppm
Pelite									
8420-R007	7	<.2	37.5	<.2	<.2	79	.5	.3	<.2
-R021	7	<.2	4.4	<.2	<.2	110	.4	.2	<.2
-R107	<5	<.2	5.5	<.2	<.2	33	<.2	<.2	<.2
-R110A	9	<.2	14.4	1.9	<.2	18	.2	.3	<.2
-R116	<5	<.2	6.1	<.2	<.2	11	.3	.2	<.2
-R143	51	<.2	4500	<.2	2.8	86	30.0	.2	1.0
8430-R049	<5	.4	3.1	<.2	<.2	15	<.2	<.2	<.2
8425-R025B	42	.6	5.5	<.2	.3	10	.6	<.2	<.2
Semipelite									
8420-R108	<5	<.2	8.0	<.2	<.2	17	<.2	.3	<.2
-R116	6	<.2	6.0	<.2	<.2	13	.3	.2	<.2
8430-R002	139	<.2	195	<.2	.6	13	1.0	2.1	<.2
-R170	70	<.2	3.0	<.2	.4	13	.5	.4	<.2
8425-R023	<5	<.2	8.1	<.2	.5	<8	.2	.4	.4
-R024	<5	<.2	16.1	<.2	<.2	15	.5	.5	<.2
Hornblende Gneiss									
8420-R117	<5	<.2	7.1	<.2	<.2	19	<.2	.4	<.2
Granodiorite									
8420-R114	<5	<.2	20.0	<.2	<.2	40	.3	.3	<.2

Table 2 - Whole Rock and Trace Element Analyses, Sulphide Lake Area. Analyses by Saskatchewan Research Council, Saskatoon

Sample No.	Oxides (percent)									Trace Elements (ppm)																
	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	P_2O_5	MnO	TiO_2	Ni[1]	Pb[1]	Au[2]	Mo	Zn	Cd	Co	Cr	V	Be	Cu	Zr	Y	La	Th	Sr	Ba
Pelite																										
8420-R024	19.8	5.65	3.51	2.47	0.93	0.16	4.71	0.063	0.50	19	4	20.0	5	89	1	12	129	99	1	9	120	4	2	3	744	405
-R029	14.8	16.65	5.91	3.51	0.21	2.92	0.81	0.215	1.91	8	2	22.0	5	154	20	29	98	63	1	5	195	51	12	3	177	106
-R031	14.1	16.90	8.41	4.28	0.13	2.72	0.29	0.255	2.14	12	2	15.0	5	187	23	42	41	452	2	43	143	37	8	3	178	85
-R033	14.6	16.76	5.35	2.82	0.02	3.90	0.82	0.201	2.01	7	2	4.2	14	131	36	29	105	73	3	14	209	52	13	3	229	56
-R073	18.8	5.22	2.61	2.37	1.17	4.99	0.15	0.049	0.49	22	5	2.8	5	107	1	12	129	94	1	15	107	6	10	3	527	365
-R075	19.0	5.17	3.40	2.19	1.19	4.77	0.15	0.045	0.49	23	8	2.2	18	108	1	14	101	105	1	18	97	5	14	3	584	380
-R078	18.5	7.17	4.06	3.32	0.94	5.09	0.14	0.076	0.48	26	2	1.4	9	112	6	18	123	103	3	38	101	6	15	3	727	328
-R079	18.7	6.41	4.73	3.52	1.12	4.46	0.14	0.058	0.51	29	9	2.2	11	101	2	13	208	103	2	4	106	10	128	3	807	378
-R081	19.6	5.42	3.90	2.32	0.73	5.14	0.12	0.056	0.40	22	2	3.8	13	85	2	11	76	82	1	10	101	8	12	3	758	375
-R081.5	13.7	11.94	1.11	2.92	2.36	2.10	0.10	0.065	0.30	15	19	7.5	13	81	1	8	31	33	3	10	506	24	51	3	214	889
-R082	13.4	10.20	1.79	2.85	2.18	1.89	0.04	0.033	0.17	7	29	0.7	16	160	1	1	96	18	1	11	429	39	40	8	176	442
-R083	23.7	6.96	1.48	0.67	4.44	2.19	0.54	0.174	5.76	14	12	0.5	21	101	1	42	47	761	12	6	255	20	24	3	229	3350
-R084	16.1	12.12	10.71	4.78	0.21	3.23	0.24	0.192	1.73	36	2	57.0	8	124	2	44	240	368	6	68	130	19	6	3	207	84
-R085	14.5	16.40	6.07	2.87	0.11	3.65	0.81	0.238	2.08	11	2	61.0	5	156	5	30	66	78	2	26	244	59	13	4	188	81
-R138	18.4	6.37	5.01	3.06	1.24	4.58	0.16	0.074	0.52	27	2	2.3	14	96	1	15	123	111	3	4	125	9	15	3	770	344
-R142	17.6	4.10	2.12	2.01	0.86	5.35	0.14	0.019	0.43	19	11	0.5	12	67	3	9	95	47	3	29	196	10	18	3	256	557
-R146	17.1	10.27	5.86	6.27	0.92	4.07	0.20	0.126	0.82	41	4	2.8	9	102	1	23	211	190	3	60	139	16	20	3	1002	245
8430-R005	17.6	9.71	8.42	5.27	1.91	4.69	0.56	0.134	0.94	34	11	48.0	5	99	1	26	140	221	2	151	144	25	63	4	1256	1148
-R006	16.9	11.16	9.94	6.48	2.22	3.73	0.66	0.143	1.13	38	9	16.0	5	117	1	28	95	275	1	62	129	32	75	3	1583	1182
-R007	17.0	12.53	10.54	10.03	1.93	2.69	0.98	0.136	0.73	84	9	9.3	5	125	1	31	263	385	1	13	76	24	44	3	1995	379
-R008	16.0	11.68	10.40	9.39	1.49	3.05	0.69	0.148	0.88	111	3	3.0	5	113	1	34	328	288	1	7	107	35	62	3	1859	1060
-R009	13.9	13.98	10.67	10.60	4.52	0.49	1.15	0.155	1.58	82	2	8.8	5	155	1	36	350	345	3	29	95	52	83	3	367	676
-R010	20.4	7.71	6.35	4.46	3.35	3.80	0.57	0.086	0.80	50	10	20.0	5	59	1	19	195	186	1	35	231	35	86	6	812	1010
-R011	14.7	3.07	2.32	1.59	3.09	5.90	0.19	0.028	0.28	19	15	88.0	5	50	1	8	146	56	1	102	173	8	23	5	467	932
-R014	14.5	11.87	7.88	8.63	2.59	3.31	0.86	0.127	1.20	104	6	26.0	5	120	5	31	284	278	1	89	147	46	87	3	958	1236
-R016	16.1	9.50	7.91	5.21	1.54	5.47	0.60	0.117	0.93	52	3	1.2	5	87	2	30	171	223	1	16	103	28	81	3	1272	1344
-R018	13.0	11.27	13.20	11.60	0.84	2.38	0.58	0.161	0.75	194	2	5.2	5	122	1	42	606	268	1	4	93	24	29	3	1055	297
-R021	17.9	9.38	7.72	5.68	0.78	4.55	0.21	0.162	0.76	34	4	5.5	5	91	1	25	174	189	1	27	153	25	22	3	1342	503
-R061	16.2	7.44	7.67	3.93	2.65	2.09	0.17	0.134	0.52	34	3	0.6	5	83	2	16	183	118	1	30	145	18	18	3	656	497
-R066	16.6	8.71	6.61	6.39	1.40	3.28	0.18	0.103	0.67	35	5	0.5	5	96	1	24	217	172	1	1	181	22	25	3	904	586
-R068	18.7	5.83	7.03	2.99	0.29	3.99	0.15	0.094	0.53	35	7	0.5	5	51	1	14	265	112	1	6	148	15	16	3	1479	186
Quartz veins																										
8420-R139	1.3	0.74	0.17	0.24	0.09	0.27	0.03	0.006	0.03	10	2	11	6	25	4	2	463	14	1	8	69	2	3	3	17	47
-R017C	1.5	0.83	0.30	0.10	0.02	0.68	0.01	0.003	0.01	7	19	103,000	10	1596	5	1	446	1	1	19	42	1	1	3	27	11
Semipelite/metatuff																										
8430-R002	13.3	4.23	1.27	1.59	5.36	2.16	0.06	0.030	0.33	6	19	51	11	64	4	5	208	4	1	47	222	27	10	3	238	922
-R013	13.9	2.14	0.16	0.66	9.83	1.03	0.02	0.019	0.21	3	26	2	5	80	1	3	123	1	1	5	355	33	7	8	129	1113
-R019	18.3	12.74	9.74	7.61	1.42	1.77	0.13	0.167	1.40	120	2	5.3	5	118	1	41	363	361	2	74	89	25	7	3	262	145
-R020	18.8	5.61	4.25	2.58	0.94	5.14	0.15	0.073	0.52	19	2	1.2	5	89	1	16	109	109	1	26	123	10	15	6	636	326
-R059	19.1	12.26	7.93	5.57	0.61	3.01	0.17	0.140	1.52	65	2	0.7	5	96	3	41	264	309	2	15	113	24	5	3	299	292
-R063	18.1	6.82	5.15	3.39	1.33	4.85	0.23	0.086	0.47	17	9	0.5	5	79	2	16	112	120	2	36	151	20	30	3	1707	976
-R070	16.6	8.28	6.77	4.42	1.32	3.76	0.24	0.071	0.67	28	10	7.3	5	98	1	20	107	164	1	37	130	20	27	3	1364	552
8420-R022	17.7	4.91	3.93	2.25	1.00	4.79	0.15	0.066	0.47	18	4	7.0	5	95	1	12	97	85	1	7	106	5	12	3	585	300
Basic Metavolcanics, Hornblende Gneiss																										
8430-R015	15.3	11.17	11.33	9.85	1.40	3.30	0.66	0.144	0.88	102	6	3.0	5	111	1	31	286	270	1	10	95	27	61	3	1832	909
-R017	10.5	16.20	13.00	12.01	0.77	1.78	0.48	0.170	1.63	120	3	221.0	5	118	1	48	325	462	3	6	127	37	35	3	726	366

[1] correction has been made for background interference

[2] in ppb

References

Carpenter, R.H., Chao, T.T., Crone, W., Larson, L.T. and Sanzolone, R.F. (1984): A comparison of iron oxide-rich joint coatings and rock chips as geochemical sampling media in exploration for disseminated gold deposits; J. Geochem. Explor., v20, no2, p161-178.

Forsythe, L.H. (1971): The geology of the Nemeiben Lake area (east half) and the geology of mineral deposits in the Nemeiben Lake - Stanley areas; Sask. Dep. Miner. Resour., Rep. 115 (Pt.2).

Project 8409

Biogeochemical Investigations, Goldfields Area

by T.I.I. Sibbald and G. Buller

Sibbald, T.I.I. and Buller, G. (1984): Biogeochemical investigations, Goldfields area; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The investigation was undertaken to examine the response of specific biogeochemical media within an area of known gold mineralization. Studies have shown that gold can be absorbed by many plants (Boyle, 1979) and more recently work in northern Saskatchewan by Dunn (1980, 1983) has demonstrated that in proximity to gold mineralization gold is concentrated in forest litter and is preferentially absorbed by speckled alder (Alnus rugosa) twigs.

The current investigation used as sample media tree bark gathered primarily from white spruce (Picea glauca) and to a lesser extent from black spruce (Picea mariana) and jackpine (Pinus bansiana). Some alder (Alnus rugosa) twig samples were also collected. In the survey area white spruce is the most widely distributed of the four species, followed by jackpine, black spruce and alder. Alder tends to be restricted to the lower lying, wetter areas of limited extent in the region, which is topographically rugged and has 50 percent or more outcrop. Jackpine is confined to and dominates dry uplands. Because of this irregular distribution both species were unsuitable for a broad scale survey. White spruce was chosen as the most appropriate sample species since it had been shown that conifer bark tends to concentrate gold (Dunn, in press). Sampling was undertaken during the period June 28 to July 13.

Area of Study

The survey area, located in the north shore of Lake Athabasca 15 km south of Uranium City, comprises some 25 km^2 and surrounds several historic gold occurrences discovered in a gold exploration boom in the thirties. This boom led to establishment of the town of Goldfields and development of two main prospects, the Box mine to the northwest of Neiman Bay and the Athona mine to the southeast. The Box mine, owned by the Consolidated Mining and Smelting Company of Canada Ltd., operated between 1939 and 1942 and produced, from underground, some 1,866,000 g (60,000 oz.) of gold from ore grading around 1.8 g/t (0.05 oz./ton) Au. The Athona mine never reached production status, although two shafts were sunk and development work undertaken on the 38 m (125-foot) and 61 m (100-foot) levels. The grade of ore was somewhat higher than that at the Box Mine and averaged around 2.7 g/t (0.08 oz./ton) gold (Christie, 1953).

The Box and Athona mines and other major gold showings have similar characteristics. Gold mineralization is hosted by 'late' granitic rocks, cut by quartz vein systems. Gold occurs free, with pyrite, galena and sphalerite, at the Athona mine and in pyrite, with generally lesser amounts of galena and sphalerite, at the Box mine. Gold, while concentrated in the quartz veins, is also present in association with disseminated pyrite in the host granites. The Box granite and surrounding rocks are cut occasionally by thin pitchblende veins, which also contain euhedral quartz, carbonate, hematite and chlorite, and by irregular pitchblende-bearing carbonatized and hematized alteration zones. In the Box granite these may show high gold and silver values (Koeppel, 1968; Ruzicka and Littlejohn, 1982; Sibbald, unpubl data). Pitchblendes from the veins yield discordant U/Pb and Pb/Pb ages; however, the U/Pb data fall on a lead loss line with an upper intersection on concordia at 1125 Ma and a lower intersection at 290 Ma (Koeppel, 1968, Fig. 6). These radiometric data in conjunction with field observations suggest that the uranium veins, as others of complex mineralogy and geochemistry in the Nicholson Bay - Fish Hook Bay area, are of sub-Athabasca Group unconformity type and thus much younger than the main gold mineralization event at Goldfields, which is of Hudsonian (ca. 1750 Ma) age or older (Sibbald et al., 1983).

Field Procedure

The area was sampled during routine pace-and-compass traverses designed for geological mapping. Some sampling was also done along shorelines. Samples were collected about every 75 m along traverse lines and sporadically along shorelines. In some areas, notably on the Athona Peninsula southeast of Neiman Bay, a recent burn restricted the availability of material. Additionally, in the area surrounding the Box mine, tree cover was limited because of cutting.

Bark samples were collected from the outer trunk, preferably of more mature trees with well-developed bark, by scraping off sufficient material to half fill a 10 by 20 cm sample bag. This amount was judged to be sufficient to yield approximately 20 g of dry bark and thence the 0.5 g of ash required for a detection limit of 5 ppb Au using neutron activation analysis.

Alder twigs were sampled by cutting the latest 50 cm (two hand spans, commonly representing some 2 to 3 years) of growth from branches in sufficient quantity to fill a 20 by 40 cm bag. This yielded from 0.5 to 1.5 g of ash when processed. The breakdown of samples collected is indicated in Table 1.

Analytical Procedure

Preparation followed procedures outlined by Dunn (1983). Samples were dried in a microwave oven to remove moisture. Alder leaves and twigs were separated after drying. Twenty-five grams of dry bark or about 50 g of twig material were placed in preweighed aluminium trays and ashed in a kiln at 475°C for approximately 24 hours. The ashed samples were analyzed for Au, U and Zn by neutron activation at Nuclear Activation Services Ltd., Hamilton, Ontario. Detection limits are 5 ppb for Au, 0.1 ppm for U and 20 ppm for Zn. All quoted analytical values represent concentrations in ashed material prepared as above.

Data Interpretation

Gold:

The gold data are summarized in Table 1. The general levels of concentration in the different sample media are similar to those recorded in regional and gold prospect specific biogeochemical surveys of shrubs and trees in northern Saskatchewan. For example, gold concentration in alder twig samples collected along the roads from La Ronge to Stanley Mission and Otter Lake range from below detection to 130 ppb and in proximity to the Box Mine from 17 to 217 ppb (Dunn, 1983). In the Sulphide Lake region surveyed this summer, gold values obtained in undifferentiated black and white spruce barks range from below detection to 450 ppb (Dunn, this volume). A jackpine located near the Rottenstone Ni-Cu-Pt-Pd-Au deposit yielded 140 ppb gold in bark (Dunn, in press).

The spatial variation in gold concentration in black and white spruce barks is illustrated in Fig. 1. High values of gold were obtained in the vicinity of the Box mine, both over the auriferous 'mine granite' and over adjacent rock units. Samples collected over the granite yielded 95 and 120 ppb Au in black spruce and 200 ppb Au in a white spruce. Other high values were found in both spruce species in areas underlain by granitoid rocks, which encompass the 'mine granite', and by quartzites and intrusive amphibolites which structurally underlie these granitoids. The highest value (625 ppb Au) from the survey was obtained

Table 1 - Ranges and mean values for gold, uranium and zinc for the sample populations

Species	Medium	n	Gold (ppb)		Uranium (ppm)		Zinc (ppm)	
			Range	Mean	Range	Mean	Range	Mean
White spruce (Picea glauca)	Bark	82	5-430	(31)	0.6-22.6	(3.3)	520-2200	(1270)
Black spruce (Picea mariana)	Bark	29	6-625	(70)	1.4-35.8	(7.9)	290-2200	(1272)
Jack pine (Pinus banksiana)	Bark	15	9-190	(43)	3.7-854	(20.8)	680-2800	(1638)
Speckled alder (Alnus rugosa)	Twigs	12	9-45	(23)	0.1-1.1	(0.5)	190-2200	(822)

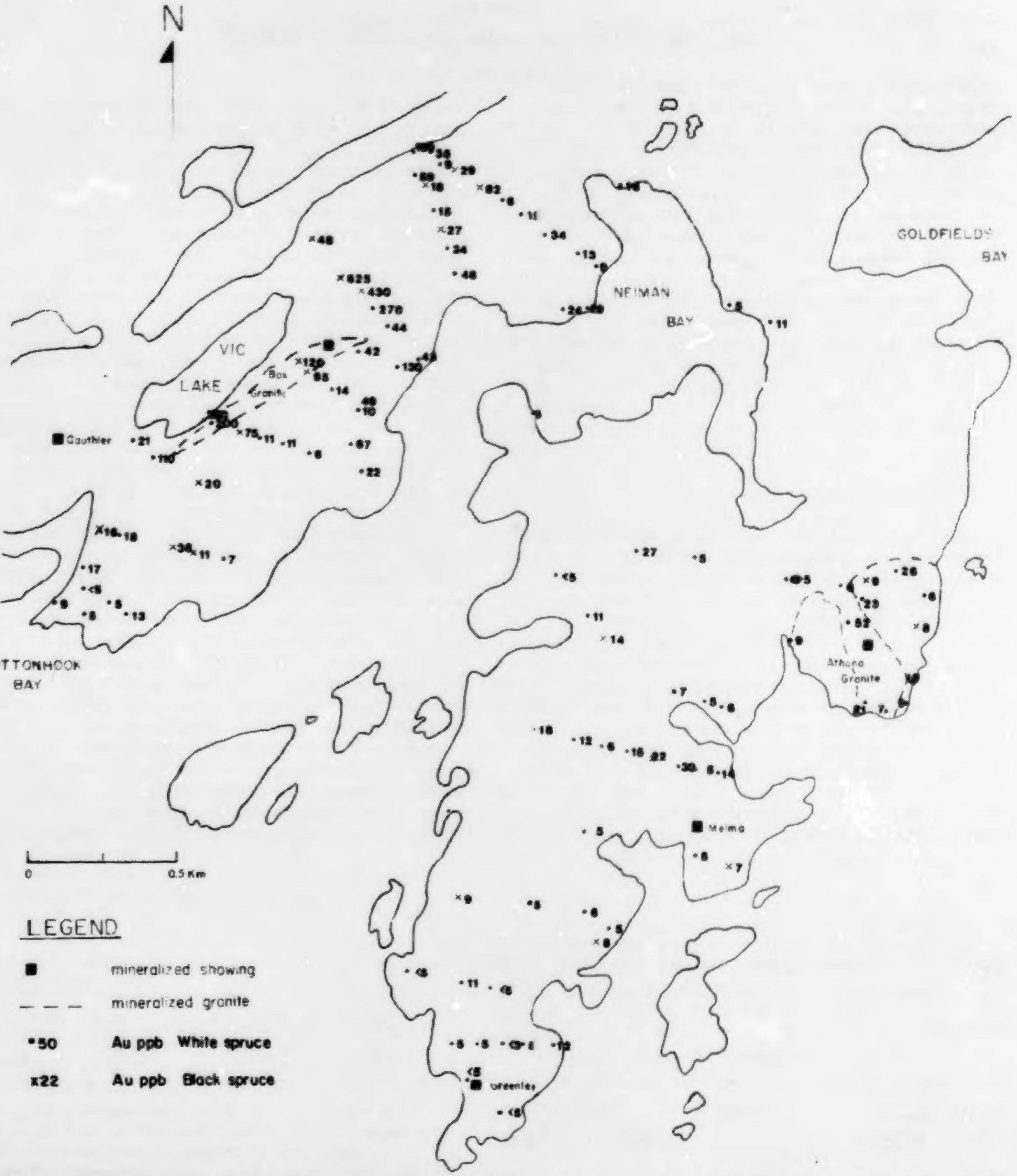
N
VIC LAKE
Box Granite
Gauthier
NEIMAN BAY
GOLDFIELDS BAY
BUTTONHOOK BAY
Athona Granite
Melma
Greenlee
0
0.5 Km
LEGEND
mineralized showing
mineralized granite
•50 Au ppb White spruce
x22 Au ppb Black spruce

Figure 1 - Gold concentration in ash of black and white spruce barks.

from a black spruce located in a drift-covered valley underlain by quartzite and amphibolite a short distance upslope and northeast of the tailings in Vic Lake.

In contrast to the Box mine area, vegetation surrounding the Athona mine is typified by relatively low concentrations of gold in analyzed samples. Those collected over the auriferous granite, which hosts the higher grade zones of gold-bearing quartz veins, showed concentrations ranging from 6 to 26 ppb Au. Samples underlain by amphibolite, which is intruded by the granite, contained from 6 to 52 ppb Au.

Similarly, over the Greenlee occurrence on Strike Point, gold concentration in a sample of white spruce bark fell below the detection limit of 5 ppb. An alder twig sample from the same site yielded an unimpressive 25 ppb Au.

Sampling of jack pine bark and alder twigs was irregular and for the most part divorced from zones of known mineralization, although four jack pine samples were collected 0.5 km south of the Box mine over a trenched zone in granitoid rocks containing disseminated pyrite and low-grade gold mineralization. Values from 24 to 80 ppb Au were obtained, suggesting jack pine bark as a potentially useful sampling medium. A white spruce sample from the same area yielded 67 ppb Au. In general, however jack pine and alder data serve only to illustrate levels of gold concentration which are likely to be encountered in these sample media in an 'auriferous area'.

Comparative data for gold, acquired from sampling different media at the same site, are shown in Table 2. The following patterns are suggested. Gold concentrations in alder twigs are 2 to 5 times higher than those in white spruce bark in two comparative sample sets. Alder concentrations also are 1.3 to 2 times higher, when compared with jack pine in two out of three sample sets. However, the data are restricted to a few sites and should be interpreted with caution, in that many factors may contribute to variations in concentration at a given sample site, both within the same and between different media. For example, individual plants draw nutrients from differently located root systems and thence may tap different metal concentrations; the age of the plant may be a factor influencing metal concentration level, which may also vary within the sample medium itself (i.e. in inner live and outer dead bark).

Uranium:

Uranium concentrations, in barks of the two spruce species and of jack pine (Table 1) are similar to levels encountered in black spruce twigs in northern Saskatchewan (Dunn, 1982, 1983). Background in ash of black spruce twigs has been found to be less than 5 ppb U, whereas uraniferous areas have yielded samples with up to 2270 ppm U at Rabbit Lake and up to 290 ppm U around Uranium City.

Fig. 2 illustrates the spatial variation in uranium concentration in black and white spruce bark samples. The highest uranium values occur in the Box mine area and there is a good correlation with the highest gold results. Similarly, jack pine bark, which had a good gold response (24 to 110 ppb Au) in the trenched area 0.5 km south of the Box mine, showed also the highest uranium values (29.6 to 85.4 ppm U) for samples of this media.

This association of gold and uranium is not clearly supported by bedrock data. The Box 'mine granite', while having a relatively high uranium content of around 7 ppm (about 2 times the average for granitic rocks), is not strongly anomalous. Late pitchblende veins cut the 'mine granite' and also the granitoids of the trenched area south of the Box mine, where jack pine shows anomalous uranium and gold. However, these veins are of extremely limited extent and it is uncertain therefore if they would significantly enhance the overall uranium content. The Athona 'mine granite' also shows a relatively high uranium content of around 8 ppm, but is characterized by background response for uranium in the vegetation. It is not known to be cut by any late pitchblende veins.

Comparative data obtained for uranium concentrations in the different sample media at the same site are shown in Table 2. Comparative studies over the Radiore uranium zone east of Uranium City by Dunn (1983) suggest that alder leaves and twigs are poorer concentrators of uranium than black spruce and jack pine twigs. Levels of concentration differ by a factor of 10. The range of mean values of uranium concentration recorded for the sample populations (Table 1) and the comparative results (Table 2) support Dunn's observations and show alder twigs as a poorer collector of uranium than the barks of jack pine and black and white spruce. Again there is an order of magnitude difference in concentration levels. The uranium data do not suggest wide variations in concentration ability within the three types of bark samples and therefore do not indicate a preferred sample medium for this metal.

Zinc:

There is no discernible pattern of zinc concentration. Ranges (Table 1) in the different survey media are rather restricted and similar in their upper limits. This suggests that factors within the plants themselves may be determining concentration rather than the metal supply available.

Conclusions

The following conclusions can be drawn from the above:

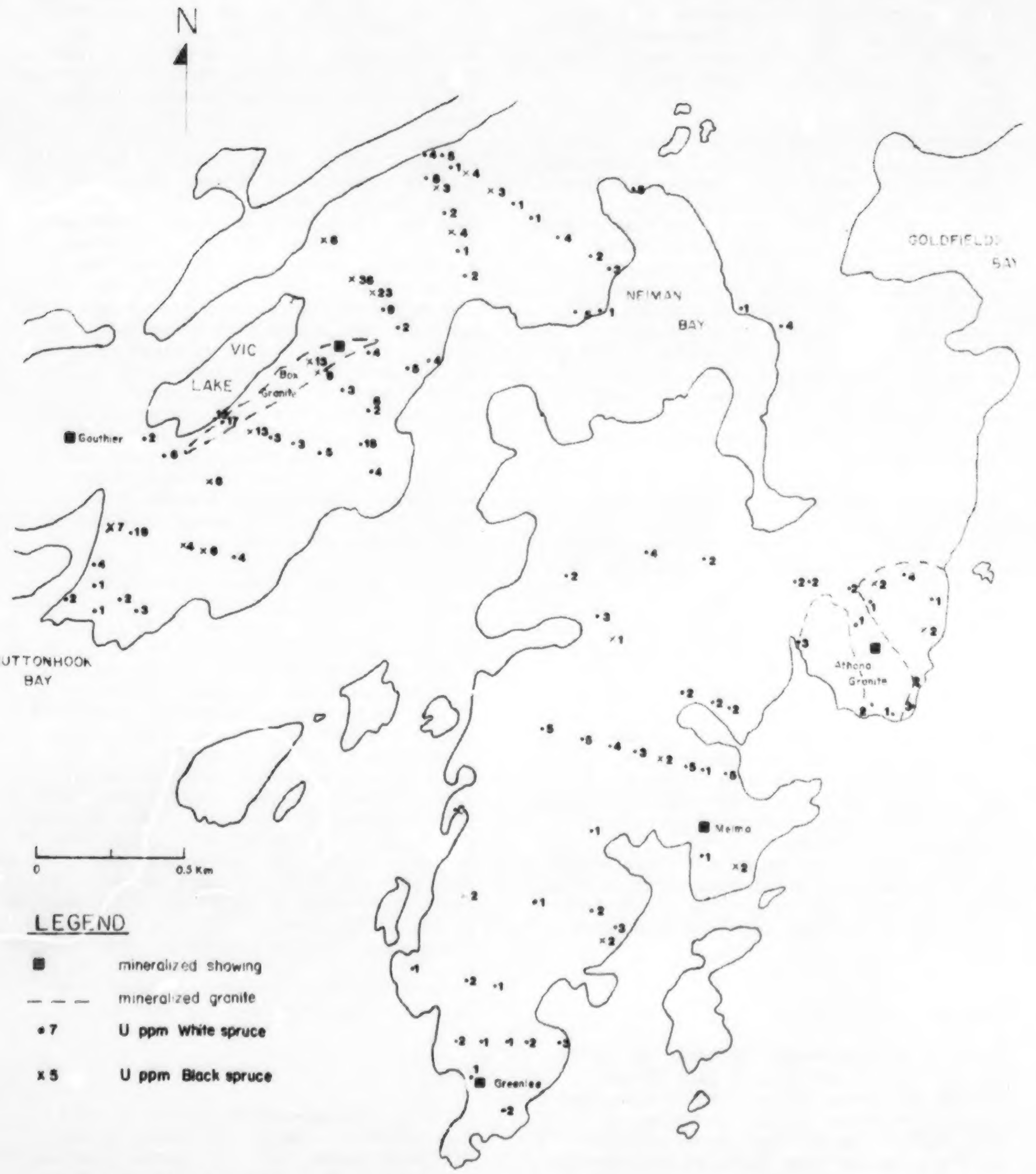
N
VIC
LAKE
Box
Granite
Gauthier
NEIMAN
BAY
GOLDFIELDS
BAY
BUTTONHOOK
BAY
Athona
Granite
Melmo
Greenlee
0
0.5 Km
LEGEND
mineralized showing
mineralized granite
• 7 U ppm White spruce
x 5 U ppm Black spruce

Figure 2 - Uranium concentration in ash of black and white spruce barks.

1) All the sample media were capable of concentrating gold in measurable quantities and thence of outlining anomalous gold zones.

2) A bedrock zone of anomalous gold, the Box 'mine granite' was defined by black and white spruce bark samples; however, there was no indicative response over an equally auriferous body, the Athona granite. The environments of both mineralizations are similar, although gold occurs primarily in pyrite at the Box mine and as free gold on the Athona property.

Table 2 - Comparative data for gold and uranium. Each sample pair is from a different sample site.

Sample pair (Nos. and Species)	Alder A (A)	White Spruce (W)	Jack Pine (J)	Black Spruce (B)
Gold (ppb)				
001A/001W	35	17	-	-
012A/058W	25	5	-	-
004A/001J	45	-	190	-
007A/009J	25	-	19	-
010J/005B	-	-	19	36
005A/002J	35	-	17	-
005W/008J	-	29	60	-
012W/017W	-	49-10	-	-
Uranium (ppm)				
001A/001W	0.4	3.8	-	-
012A/058W	0.8	2.7	-	-
004A/001J	0.4	-	5.3	-
007A/009J	0.8	-	12.7	-
010J/005B	-	-	5.7	3.6
005A/002J	1.1	-	7.0	-
005W/008J	-	13.1	4.9	-
012W/017W	-	5.6 -1.9	-	-

3) Several gold anomalies unrelated to known bedrock mineralization were generated by the survey.

4) High uranium values are encountered in samples collected in the area of the Box 'mine granite' and many are correlative with high gold values. Although pitchblende veins are known to cut the granite and other rock units in this area, they are of very localized importance and significantly younger and thence not obviously spatially related to the main granite-hosted gold mineralization. Thus, there is no clear cut explanation of the uranium-gold association in the vegetation samples.

5) The bark sample populations showed similar levels of uranium concentration to those encountered, to date, in anomalous populations of black spruce twigs. By contrast alder twigs contained significantly less uranium, suggesting that they are poorer accumulators and sample media for this metal.

References

Boyle, R.W. (1979): The geochemistry of gold and its deposits; Geol. Surv. Can., Bull. 280.

Christie, A.M. (1953): Goldfields - Martin Lake map-area, Saskatchewan; Geol. Surv. Can., Mem. 269.

Dunn, C.E. (1980): Gold biogeochemistry investigations: Flin Flon area; in Summary of Investigations 1980, Sask. Geol. Surv., Misc. Rep. 80-4, p81-85.

_________ (1982): Further investigations on uranium biogeochemistry in northern Saskatchewan; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p86-90.

_________ (1983): Biogeochemical investigations in northern Saskatchewan: preliminary data on tungsten, gold, platinum, rare earths and uranium; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p106-122.

_________ (in press): Biogeochemistry as an aid to exploration for gold, platinum, palladium in the northern forests of Saskatchewan, Canada; J. Geochem. Explor.

Koeppel, V. (1968): Age and history of the uranium mineralization of the Beaverlodge area, Saskatchewan; Geol. Surv. Can., Pap. 67-31.

Ruzicka, V. and Littlejohn, A.L. (1982): Notes on mineralogy of various types of uranium deposits and genetic implications; in Current Research, Part A; Geol. Surv. Can., Pap. 82-1A, p341-349.

Sibbald, T.I.I., Schwann, P.L. and Dunn, C.E. (1983): Uranium-gold metallogenic studies: Nicholson Bay ultramafic complex; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p75-79.

MINERAL DEPOSIT STUDIES

Project 8409

Gold Metallogenic Studies, Goldfields Area

by T.I.I. Sibbald

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The Goldfields area has been the subject of numerous investigations dating from the thirties. The earliest work (Alcock, 1936a, 1936b; Beavan, 1938) followed in the wake of the discovery by Tom Box of gold mineralization at the site of what was to become the Box mine of the Consolidated Mining and Smelting Company of Canada Ltd. A later period of geological study by the Geological Survey of Canada (Christie, 1953; Robinson, 1955) accompanied the intense exploration effort for uranium, initiated in 1944. At that time, a previous discovery by Alcock (1936a) of the uranium bearing hydrocarbon thucholite at Nicholson Bay, a short distance to the east of Goldfields, was one of three known occurrences of uranium minerals in Canada.

New mapping by the Saskatchewan Geological Survey at 1:31,670 and 1:20,000 scales, together with uranium mineral deposit investigations in the general region, commenced in 1980 (Sibbald and Lewry, 1980; Sibbald, 1982; Sibbald et al., 1983).

The present investigation was designed to examine in more detail than had been possible in previous studies the geological setting of the auriferous granites at Goldfields. Accordingly the area surrounding the Box and Athona mines was geologically surveyed at 1:5,000 scale. In conjunction, samples of different rock units were collected by S. Persons, University of Kansas (Project 8404) for possible zircon dating. These included the Box, Athona, Lodge Bay and Cornwall Bay granites, older feldspar augen granite from the Box mine area and quartz pebble conglomerate from the supracrustal sequence.

The Goldfields area comprises supracrustal rocks intruded by mafic bodies and at least two ages of granitic rocks (Christie, 1953; Sibbald and Lewry, 1980). Early work by Alcock (1936a) recognized two ages of supracrustals, an older Archean Tazin Group of mixed sediments and volcanics postdated by Archean granitic rocks and a younger Proterozoic Beaverlodge Series formed predominantly by quartzites. The Beaverlodge Series itself is in turn intruded by mafic bodies and 'younger' granites. The granitic rocks in the immediate proximity of Goldfields, that is the Box and Athona 'mine granites' and surrounding granitoids, were assigned by Alcock to the group of 'younger' granites.

The unconformity between the two groups of supracrustals is allegedly exposed on Box Point and on an island southeast of the point (Alcock, 1936a); however, at these localities, as at others cited by Alcock, neither Christie (1953) nor the author have found unequivocal evidence of unconformity. All supracrustals are ascribed to one group, the Tazin Group of Christie (1953) or more specifically in the Beaverlodge Lake area to the Murmac Bay Formation (Tremblay, 1972, 1978) or Murmac Bay Group (Macdonald, 1983).

The age of the Murmac Bay Group and the granitic rocks that invade it has been the subject of debate largely because of the absence of good radiometric controls. Tremblay (1972) has assigned an Archean age to the Group, whereas others (Kupricka and Sassano, 1972; Morton and Sassano, 1972; Sassano et al., 1972 and Sibbald and Lewry, 1980) have argued for a Lower Proterozic ancestry. Rb-Sr dating of the granitic bodies which intrude these rocks at Cameron Island and Mackintosh Bay has yielded good isochron ages for both granites of around 2000 Ma together with extremely high initial ^{87}Sr/^{86}Sr ratios around 0.74. Data from the Box and Athona granites has to date proved inconsistent (Bell and Blenkinsop, this volume). Since the supracrustals show no evidence of polyorogenesis (eg. markedly different superimposed regional deformation and metamorphic events) and the granites are syntectonic, a Lower Proterozoic age for the supracrustals appears most likely.

Description of Rock Types

The supracrustals are characterized by a quartzite-carbonate succession metamorphosed under lower to middle amphibolite facies conditions to yield quartzites, quartz-mica schists, dolomitic marbles, diopsidic calc-silicate rocks and amphibole schists. Way-up indications from cross-bedding in the quartzite, within and adjacent to the mapped area, are consistent in suggesting a normal southward younging succession.

Supracrustal Rocks:

The quartzites are typically white, medium to fine grained and indistinctly bedded and cross-bedded to massive. Grit and quartz pebble conglomerate layers occur locally. In addition to quartz these rocks comprise feldspar, micas and, in conglomerate layers in particular, iron oxides (hematite). Feldspar content is generally low, although some layers(?) are pink and richly feldspathic. However, as the quartzites are clearly granitized it is uncertain to what extent feldspar is sedimentary, as opposed to metasomatic. In great part the quartzites resemble the mature clastics of the Athabasca Group. As the presence of immature arkosic layers within the quartzite sequence would imply a distinctly different provenance for these layers, it appears probable that much of the feldspar is metasomatic.

The quartzites grade into micaceous quartzites and quartz-mica schists, and with the development of calc-silicate minerals into calcareous quartzites. Locally they show pink granitic segregation layers and lenses of quartz-feldspar ± tourmaline which are cut by white quartz veins.

Calcareous rocks are developed primarily in the Goldfields area, but also appear as 'relicts' within the granites on the west side of the Athona Peninsula. They comprise an often chaotically interlayered sequence of marbles, calc-silicate rocks, amphibole-mica schists and calcareous quartzites. The marbles are buff weathering, white to grey, medium grained, granular, impure dolomites containing diopside, tremolite and pale coloured mica as impurity minerals. Calc-silicates are typified by pale green diopside-tremolite rocks of coarse to pegmatitic grain size. Diopside crystals are often rimmed and replaced along fractures by pale green tremolitic amphibole, which itself may also form discrete layers. A variety of amphibole-mica schists are interlayered with these calcareous units. In different layers amphiboles may vary in colour from pale green (tremolite) to dark green (actinolite-hornblende) and micas from pale coloured (phlogopite-muscovite) to dark brown (biotite). In some layers amphiboles form radiating aggregates or rosettes up to several centimeters in maximum dimension. A rather distinctive unit occurs on the west side of the Athona Peninsula as a 'relict' within older granite. Radiating pale brown amphibole sheaves are set in a biotitic matrix partly enclosed by poikiloblasts, probably of cordierite, up to 2 cm in size.

While many of the pale amphibole-mica schist layers are gradational into distinct calcareous metasediments, those characterized by dark green amphibole and biotite are not mineralogically distinct from amphibolites of presumed intrusive origin. Where these latter form mappable units they have been differentiated and assigned to the group of amphibolites described below.

Amphibolites of presumed igneous origin form concordant to subconcordant units in the supracrustals and occur as less regular relict masses in the granitic rocks. The larger bodies up to several tens of meters thick are typically brown to green weathering, dark green, coarse to medium grained and homogeneous. In most cases they are of gabbroic to dioritic composition and comprise broadly equal amounts of dark green hornblende and feldspar and subordinate biotite. However, a large body which outcrops along the eastern side of the Athona Peninsula is locally significantly less mafic, containing around 25 percent amphibole and/or biotite and minor quartz. Compositionally it approaches quartz diorite or granodiorite. The body is invaded by up to 50 percent pink granite sheets sometimes flanked by alteration haloes marked by the growth of pink feldspar blasts and the replacement of hornblende by biotite. In the event that the alteration process is more widespread it appears probable that the more felsic character of this body derives from metasomatic changes rather than a more acid initial composition.

Internally, the larger amphibolite bodies are weakly deformed, however margins may be strongly foliated and lineated. Foliation is depicted by preferred crystallographic orientations of hornblende and biotite and lineation by the preferred orientation of the long axes of amphibole crystals and crystal aggregates. Pale green epidote and red hematite commonly infill fractures.

Smaller amphibolite bodies, particularly those forming relict layers and lenses up to a few meters wide in the granites are compositionally more varied. They contain locally garnetiferous, biotite-rich layers and pods, which typically weather recessively and lend outcrops a ribbed or pock-marked appearance. Biotitic layering is often most strongly developed adjacent to granitic rocks. This observation has led previous workers (Christie, 1953) to infer marginal alteration of the amphibolite sheets by granitic fluids (i.e. K-metasomatism).

Granitic Rocks:

Granitic rocks form the major part of the Goldfields area. Four main subdivisions of the granitic complex have been made. These are somewhat arbitrarily defined on the accompanying map as many areas are an admixture of types.

The older granitic rocks are the most common and inhomogeneous of the subdivisions. They are texturally and compositionally varied and include numerous unassimilated 'relicts' of quartzite, calcareous rocks and amphibolite. Colours range from grey to white to pink and grain size from coarse to fine. Foliation and rodding are typically well developed. Feldspar augen up to 2 cm long and mafic spots up to 1 cm long are characteristic. These latter comprise biotite aggregates, possibly after hornblende, which are elongated parallel to the regional southerly plunging rodding lineation. Mafic minerals, predominantly biotite, but also hornblende and chlorite, comprise up to 10 percent and muscovite is common in some variants, particularly around the Box mine.

To the south of this mine and on the west side of the Athona Peninsula a distinctive pink felsitic subunit is distinguished. It is extemely fine grained, almost cherty in appearance, poorly layered and foliated. It comprises quartz, feldspar, biotite and muscovite and in some layers and irregular zones, pale green, randomly oriented crystals of amphibole make up 25 percent of the rock. Muscovite-bearing quartzite and quartz-muscovite schist layers and lenses are locally present within the subunit. In some areas the rock contains disseminated pyrite and has been trenched (eg. 0.5 km south of the Box mine and on the east side of Neiman Bay opposite the mine dock).

Pink leucogranite is extensive in the vicinity of the Athona mine and on the Athona Peninsula to the south. Additionally it occurs irregularly distributed in diffuse layers and pods within the older granitoids, particularly in the Box mine area. The rock is typically poor in mafic components (5 percent) and is weakly foliated to unfoliated. Two main textural varieties are distingished, a medium grained equigranular type and a fine grained type characterized by scattered porphyroblasts of pink feldspar, up to 1 cm in size, in a pink 'cherty' felsic matrix. There appears to be a gradational transition between these two types. White quartz-filled gashes and veins occur sporadically within the leucogranites.

Pink to grey feldspar-augen granite outcrops on the southern end and eastern side of the Athona Peninsula. The rock contains feldspar augen, up to 1 cm in size, and from 5 to 10 percent biotite (chlorite). It is commonly weakly foliated and/or rodded and in places is intimately intermixed and transitional with leucogranite.

The auriferous Box and Athona 'mine granites' are characterized by the presence of disseminated pyrite and abundant quartz veins. They have been described in detail by Beavan (1938) and Christie (1953). The general characteristics of the gold mineralization are noted by Sibbald and Buller (this volume).

The Box 'mine granite' is pink to red coloured, rusty weathering, medium grained and equigranular. It is extremely leucocratic containing broadly similar amounts of quartz and feldspar and very minor chlorite and muscovite. A weak foliation marked by a micaceous parting is locally visible, however, for the most part the granite is massive. This foliation parallels schistosity in the adjacent older granite and is likely inherited from it. The 'mine granite' forms a relatively homogeneous sub-concordant lensoid body enclosed by older granite and underlying white quartzite. Within the older granite, supracrustal 'relicts' primarily of quartzite are apparent, particularly in the footwall section adjacent to the quartzite contact. Lit par lit and less regular shaped accumulations of pink leucogranite, which are compositionally similar to the 'mine granite', but lack sulphides, pervade the surrounding area.

The Athona 'mine granite' is a white to pink, coarse grained, poorly foliated to massive, equigranular to weakly feldspar-porphyroblastic biotite (chlorite) leucogranite. It invades amphibolite of gabbroic composition and older granite. Intrusive relationships are not well defined and in respect to the amphibolite have been the subject of past debate (Christie, 1953). The older granite to the north is pink weathering, weakly foliated and contains up to 10 percent biotite (chlorite). For the most part it appears to be medium grained and equigranular; however, also present is a feldspar-porphyroblastic variety, with pink feldspar crystals up to 0.5 cm in size. 'Relicts' of quartzite are enclosed by older granite at the 'mine granite' contact. The older granite to west and east comprises grey feldspar augen granite and intermixed grey granite and amphibolite respectively. The eastern contact is thought to be faulted. Chemical analyses of the Box and Athona 'mine granites' are reported in Table 1.

Structure

The area is characterized by two recognizable major deformation events. The earliest gave

Table 1 - Whole Rock and Trace Element Analyses, Box and Athona 'Mine Granites'

Sample No.	SiO_2	Al_2O_3	CaO	MgO	Na_2O	K_2O	Fe_2O_3[3]	MnO	TiO_2	P_2O_5	LOI	Sum	Au[4]	U	Th	Zn	Pb	Cu	Mo
a) Box 'mine granite'																			
GG7[1]	69.58	17.17	0.38	0.38	3.87	8.86	1.44	0.03	0.08	0.01	0.4	102.2	450	12	40	77	282	85	35
GG10	74.21	11.96	0.05	0.26	2.84	5.62	1.01	0.01	0.09	0.01	0.5	96.57	129	7	26	15	9	18	2
SF615[2]	81.6	9.46	0.22	0.19	3.84	2.39	1.26	0.01	0.08	0.03	0.85	100.0	700	7	16	13	20	8	5
SK701	76.2	12.1	0.10	0.26	3.36	5.35	0.97	0.01	0.08	0.02	0.93	99.4	270	6.7	22	26	34	39	7
b) Athona 'mine granite' (sample 8017-155, amphibolite from Athona property)																			
8017-155[1]	47.41	16.31	7.46	5.95	3.83	0.94	10.95	0.15	1.30	0.18	1.00	95.68	-	-	-	-	-	-	-
GG2	74.56	11.59	0.27	0.30	2.96	5.64	1.30	0.03	0.07	0.02	0.60	97.35	675	8	20	11	15	7	2
GG3	74.72	11.53	0.24	0.44	3.92	4.59	1.43	0.03	0.09	0.01	0.60	97.10	92	7	24	28	14	4	1
GG6	72.44	12.29	0.12	0.13	3.06	6.27	0.92	0.01	0.08	0.01	0.20	95.98	225	8	9	9	9	10	3

[1] Major elements by metaborate fusion, HNO_3 digestion and inductively coupled argon plasma spectrometry (ICP). Trace metals by HCl/HNO_3 digestion and ICP. Au by Fire Assay and AA (8017 and GG series).

[2] Major elements by XRF.
Trace metals by HCL/HNO_3 digestion and ICP. Au by fire assay and ICP, Th by neutron activation, U by neutron activation, delayed neutron counting (SK series).

[3] Total iron as Fe_2O_3.

[4] Au in ppb, all other trace metals in ppm. Major oxides are in Weight Percent.

rise to the dominant regional foliation (S_1) and to rare minor and outcrop-scale folds. Foliation (S_1) is defined by a preferred orientation of micas and amphibole and by a dimensional orientation of quartz and feldspar (augen) grains. In general, it parallels compositional layering, although discordant relationships with bedding (S_0) are apparent in the quartzites west of Buttonhook Bay and with compositional layering in amphibolite sheets in older granite on Box Point. The intersection of the two structures plunges south-southeast and is marked by a rodding fabric. Isoclinal folds present in interbanded calc-silicate and marble on the south side of Goldfields Bay have similarly oriented fold axes.

The regional foliation (S_1) is folded into a major open syncline or synclinorium, whose axial surface trace passes through the townsite of Goldfields and the Athona Mine. The structure plunges gently to moderately to the south and the axial surface trace is northerly trending. Open minor folds related to this major structure are common and have similarly oriented fold axes and subvertical axial surfaces. Axial plane schistosity (S_2) is locally developed. In general it is a weakly defined feature, although zones of more intense S_2 fabric occur on the west side of the Athona Peninsula.

Most rocks display a pronounced rodding fabric marked by preferred crystallographic and dimensional orientations of minerals and mineral aggregates. This lineation is coaxial with second generation folds and appears to be the product of the same deformation event, although a note of caution is introduced into this interpretation by the apparent parallelism of S_0/S_1 intersection rodding fabrics.

Strain markers are uncommon and restricted to a few layers in the quartzite sequence which contain recognizable quartz clasts. Clasts generally appear to be neither strongly flattened nor elongated suggesting a relatively low strained state for the rocks of the area.

The structural events described above provide an important time reference for the emplacement of the granitic rocks. The older granites retain structures of both deformation events, in contrast to the other granitic subunits which record only the effects of the second. In the feldspar-augen granite second generation structures are often clearly defined, whereas they are weak or not apparent in the leucogranite and 'mine granites'. This variation may reflect compositional differences; the mafic biotite (chlorite) rich feldspar-augen granite was able to acquire mesoscopically recognizable fabrics in contrast to the virtually mafic free leucogranite and 'mine granites'.

Discussion

In the Goldfields-Beaverlodge area previous workers have recognized a variety of granitic rocks and have noted the gradational relationships which often exist with the supracrustals. Debate has centered around which granites, if any, are intrusive. For example, Cooke (1937) has argued that the Box 'mine granite' is intrusive within granitized quartzites, whereas Swanson (1945) concluded that the body was "composed of sediments more granitized than usual". Beavan (1938) described the Athona 'mine granite' and the Mackintosh Bay granite further east as magmatic. Christie (1953) interpreted most granites to be of replacement type except the

Mackintosh Bay and some other small bodies. The author is in general agreement with Christie.

Much of the variation in character of the granitic rocks likely results from differing degrees of granitization as proposed by Swanson (1945). Initial supracrustal composition is also a factor in determining the end product as well as the nature of contact relationships. Contacts with quartzite units appear gradational, particularly along strike suggesting that these rocks provided little resistance to invading 'solutions', whereas those with amphibolites are sharp with only limited metasomatic border effects. In addition to these complications, there are at least two main granite emplacement episodes, predating the first and second deformation events respectively. The second episode possibly occurred around 2000 Ma, based on Rb-Sr dating of the Mackintosh Bay granite (Bell and Blenkinsop, this volume). This body shows only structures of the second deformation event or no mesoscopically visible structure; characteristics typical of the feldspar-augen granite, leucogranite and 'mine granites' at Goldfields.

Also recognized within the 'mine granites' by previous workers (Beavan, 1938; Christie, 1953) is a late albitization episode. Albite replaces K-feldspar and forms thin quartz-albite veinlets. In addition, small bodies of albitite are reported in both 'mine granites'. Albitization phenomena are widespread in the Beaverlodge area and in many instances are related to the earliest generation of epigenetic pitchblende mineralization (Dawson 1956; Hoeve, 1982) dated at 1780±20 Ma (Koeppel, 1968). It is uncertain whether the albitization episode in the 'mine granites' is of the same age.

While details of the granite emplacement process are obscure, the author's observations suggest significant *in situ* replacement of supracrustal rocks. For example, the Box 'mine granite' appears to be the product of feldspathization of sediments, predominantly quartzites. There is no evidence that this body, or the granite complex as a whole, was derived simply by *in situ* transformation of original quartzofeldspathic sediments (eg. arkoses) by anatexis. The mature aspect of the quartzite-carbonate succession speaks against the interlayering of such rocks in the succession.

The gold mineralization may derive from either a pre-existing accumulation in the precursor supracrustals or may have been introduced during the granitization (feldspathization) process. Bedrock samping has not identified significantly anomalous gold concentrations in the supracrustals, although a variety of potentially auriferous rock types has been recognized (Sibbald, 1982; Sibbald et al., 1983). Quartz pebble conglomerates exposed in Lodge Bay and representative of a possible paleoplacer source were sampled during the current field program. Analytical results are shown in Table 2 for the eleven locations sampled. A maximum of 4 ppb gold was obtained.

In the event that the gold mineralization has been introduced during feldspathization, the second period of granite emplacement appears most conducive to formation of gold concentrations. The concentration process remains enigmatic.

Table 2 - Trace Metals in Quartz Pebble Conglomerate

Sample No.	Pb	Ni	Co	Cu	Zn	Au
8409 31	5	5	1	3	3	1.8
9409 69	2	4	1	3	2	0.5
8409 70	5	5	1	4	2	1.5
8409 71	2	4	1	2	3	1.3
8409 72	3	4	1	19	2	0.5
9409 73	3	5	1	3	2	1.1
8409 74	2	5	1	4	3	2.1
8409 74A	2	5	1	2	2	1.8
8409 75	3	7	1	3	5	0.5
8409 76	2	13	2	3	6	4.4
8409 77	4	8	1	2	3	0.5
8409 77A	3	7	1	2	3	0.8
8409 78	7	5	1	4	2	0.8

Trace metals by HCl/HNO_3 digestion, and AA; Au by MIBK extraction and AA. Au in ppb, all other trace metals in ppm.

References

Alcock, F.J. (1936a): Geology of the Lake Athabaska region, Saskatchewan; Geol. Surv. Can., Mem. 196.

__________ (1936b): The gold deposits of Lake Athabaska; Trans. Can. Inst. Min. Metall., v39, p531-546.

Beavan, A.P. (1938): The geology and gold deposits of Goldfields, Lake Athabaska, Sask.; unpubl. Ph.D thesis, Princeton University.

Christie, A.M. (1953): Goldfields - Martin Lake map-area, Saskatchewan; Geol. Surv. Can., Mem. 269, 126p.

Cooke, H.C. (1937): Preliminary report, Goldfields area, Saskatchewan; Geol. Surv. Can., Pap. 37-3.

Dawson, K.R. (1956): Petrology and red colouration of wall-rocks, radioactive deposits, Goldfields region, Saskatchewan; Geol. Surv. Can., Bull. 33.

Hoeve, J. (1982): Perspective on uranium mineralization at Beaverlodge; Sask. Res. Counc., Publ. G-745-1-E-82.

Koeppel, V. (1968): Age and history of the uranium mineralization of the Beaverlodge area, Saskatchewan; Geol. Surv. Can., Pap. 67-31.

Krupicka, J. and Sassano, G.P. (1972): Multiple deformation of crystalline rocks in the Tazin Group, Eldorado Fay Mine, northwest Saskatchewan; Can. J. Earth Sci., v9, p422-433.

Macdonald, R. (1983): Geology and regional context of the Oldman Lake area; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p19-23.

Morton, R.D. and Sassano, G.P. (1972): Structural studies on the uranium deposit of the Fay mine, Eldorado, northwest Saskatchewan; Can. J. Earth Sci., v9, p803-323.

Robinson, S.C. (1935): Mineralogy of uranium deposits, Goldfields, Saskatchewan; Geol. Surv. Can., Bull. 31.

Sassano, G.P., Baadsgaard, H. and Morton, R.D. (1972): Rb-Sr isotopic studies of the Foot Bay gneiss, Donaldson Lake gneiss and pegmatite dykes from the Fay Mine, NW Saskatchewan; Can. J. Earth Sci., v9, p1368-1381.

Sibbald, T.I.I. (1982): Uranium metallogenic studies: Nicholson Bay area; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep. 82-4, p43-45.

Sibbald, T.I.I. and Lewry, J.F. (1980): Uranium metallogenic studies: Lodge Bay area, Lake Athabasca; in Summary of Investigations 1980, Sask. Geol. Surv., Misc. Rep. 80-4, p44-48.

Sibbald, T.I.I., Schwann, P.L. and Dunn, C.E. (1983): Uranium-gold metallogenic studies: Nicholson Bay ultramafic complex; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4, p75-79.

Swanson, C.O. (1945): Probabilities in estimating the grade of gold deposits; Can. Inst. Min. Metall. Bull., v48, p323-350.

Tremblay, L.P. (1972): Geology of the Beaverlodge mining area, Saskatchewan; Geol. Surv. Can., Mem. 367.

__________ (1978): Geologic setting of the Beaverlodge-type of vein-uranium deposit and its comparison to that of the unconformity-type; in Short Course in Uranium Deposits: Their Mineralogy and Origin; Mineral. Assoc. Can., Handbook, v3, p431-456.

Project 8425

Gold Metallogenic Studies, Sulphide Lake Area

by T.I.I. Sibbald

Sibbald, T.I.I. (1984): Gold metallogenic studies, Sulphide Lake area; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

A small area around Sulphide Lake was geologically mapped at 1:20,000 scale as the beginning to a study of the geological setting of gold mineralization in the Sulphide Lake gold camp. The area contains the Studer A, B, C, D and E, Galena, Lucky Strike and Discovery gold zones.

Previous studies by the Saskatchewan Geological Survey were undertaken by Forsythe (1968, 1971) and Coombe (1976).

The area comprises volcanic and sedimentary rocks apparently intruded by metagabbro and weakly porphyritic biotite granodiorite. Metamorphic grade is within the upper greenschist to lower amphibolite facies range. The volcanic rocks in the vicinity of the Studer and Galena gold zones are interpreted as predominantly felsic to intermediate tuffs. These give way to the northwest to more mafic volcanics, tuffs and possibly flows and to the southeast to pelitic to semipelitic metasediments. Poorly developed graded bedding suggests an inverted succession younging to the southeast.

The felsic to intermediate tuffs comprise monotonous, grey to green, fine-grained and finely foliated generally poorly layered rocks. In part they are feldsparphyric with feldspar 'clasts' up to 0.5 cm in size. The mafic content, which forms one basis of lithological subdivision, varies from less than 10 percent to 30 percent in different layers. Sporadically interlayered fine grained sediments are locally black and carbonaceous. To the northeast of the Studer A and B zones is a well defined unit of pillowed volcanics of possibly andesitic composition.

The area shows evidence of two deformation events. The first produced the regionally developed layer-parallel schistosity, which trends northeasterly and dips moderately to steeply northwesterly. Minor folds of this age are rare and major structures apparently absent. The second caused major open folding and widespread minor folding. Minor folds are open to close, plunge to the north and axial surfaces trend north-northeast and dip steeply west.

The Studer and Galena gold zones appear closely related to the argillaceous carbonaceous sediments. Gold with arsenopyrite, pyrite and locally galena and chalcopyrite occurs in quartz veins and gashes and is associated with sulphide disseminations in bedrock. The mineralization is not unique to the cabonaceous argillites, as it is also present in the bounding interlayered volcanics and sediments. Mapping suggests that the Studer A and B and Galena zones lie within the same stratigraphic unit (see also Forsythe, 1971; Coombe, 1976). The Studer C, D and E zones may occur at one or more other stratigraphic levels in sedimentary zones of similar character.

The carbonaceous sediments clearly reflect a low rate of sedimentation related to a hiatus in volcanism and in this respect formed a suitable environment for seafloor concentration of metals.

The Lucky Strike and Discovery gold zones are of differing character and occur in quartz veins in the porphyritic granodiorite. This body may represent a subvolcanic intrusive associated with the tuff volcanism.

References

Coombe, W. (1976): La Ronge-Wollaston Base Metals Project; in Summary of Investigations 1976, Sask. Geol. Surv., Misc. Rep., p.99-103.

Forsythe, L.H. (1968): Geology of the Stanley Area (West Half), Saskatchewan; Sask. Dep. Miner. Resour., Rep. 115, Pt. 1, 58p.

__________ (1971): Geology of the Nemeiben Lake Area (East Half) and Geology of the Mineral Deposits in the Nemeiben Lake-Stanley Areas, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 115, Pt. 2, 178p.

Project 8414

Gold Metallogenic Studies, The Rio Deposit

by J.G. Pearson

Pearson, J.G. (1984): Gold metallogenic studies, the Rio deposit; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The Rio gold deposit of Flin Flon Mines Ltd., located 3 km south of Creighton, is unique in the Flin Flon area because of the mineralogy of the pyrite-gold ore, its location on the Rio Fault and the associated chert-carbonate alteration zone. The geological setting of the deposit has been described previously by Stockwell (1960), Byers et al. (1965), Pearson (1979) and Pearson (1983). In this program an area of 750 m by 750 m around the deposit was mapped at a scale of 1:1200 with particular attention devoted to the stratigraphy and structure.

General Geology

The rocks around the deposit comprise a westerly-facing homoclinal sequence of basalt and debris flows with minor extrusive and intrusive bodies of rhyolite and dacite. This sequence has been intruded by the Boot Lake pluton and the Phantom Lake granite. Around the deposit there is widespread evidence of fracturing, presumably as a result of movements on the Rio Fault.

Description of Rock Types

Basalt occurs as fine-grained, dark green massive flows on both the hanging wall and footwall of the Rio Fault. Pillow lavas, although clearly recognizable in places, commonly become flattened, fractured and silicified and thence indistinct near the Rio Fault. Many of the flows contain large irregular pods of commonly amygdaloidal, quartz-epidote material set in a fine-grained basaltic matrix. These pods are still recognizable in all but the most intensely altered and deformed parts of the fault zone. Flow breccias, comprising amoeboid-shaped fragments in a flow-banded matrix, are also common. Where the basalts have an intrusive rather than fault-controlled contact with the Boot Lake Pluton, they develop small granitoid patches and show an increase in grain size and a change in composition of the amygdules from quartz-epidote-carbonate to quartz-amphibole adjacent to the pluton.

Porphyritic basalt is present in the western part of the map area and rarely shows any volcanic structures. Plagioclase phenocrysts up to 5 mm in diameter are typical and smaller mafic phenocrysts (up to 2 mm), presumably pyroxene pseudomorphs, are also often developed.

Plagioclase phyric debris flows form the major rock unit on the hanging wall side of the Rio Fault. They are massive to crudely bedded polymictic fragmentals. The ratio of clasts to matrix varies from 0 to 60 percent. Fragment types include amygdaloidal basalt, plagioclase and plagioclase-'pyroxene' phyric basalt, aphyric basalt, felsic epidote fragments, andesite, dacite and, rarely, rhyolite. Fragments vary in size from 1.5 mm to 75 cm and in shape from well rounded to angular. Bedding is rare, although occasional small silt-filled scour channels and pockets of fine-grained bedded sediment are observed. These features provide inconclusive indications of a westerly-facing direction. Rarely there is a suggestion of graded bedding but, more commonly, a chaotic mixture of fragment sizes and types prevails. Some outcrops are massive and fine grained (<1 mm) and resemble closely the porphyritic basalts. The debris flows also exhibit zones of patchy calcite alteration, similar to that described at the Amisk Syndicate occurrence in the East Amisk Lake area (Pearson, 1982). Within these zones siliceous fragments remain as positively weathering masses and spikes while the surrounding basalt-calcite matrix weathers up to 5 cm lower. This alteration provides a means of distinguishing the fine-grained debris flows from the porphyritic basalts. The matrix of the debris flows consists of randomly oriented plagioclase phenocrysts (up to 3 cm) and very fine grained mafic minerals.

Interlayered with the debris flows are narrow lenses of intermediate to acid fragmentals consisting of rhyolite, dacite and basaltic fragments in a basaltic matrix. In one outcrop this unit is present as a pebble dyke.

White-weathering dacitic to rhyolitic dykes, sills and/or flows, composed of feldspar and rare quartz phenocrysts (up to 3 mm) set in a very fine grained siliceous matrix, occur in the western half of the mapped area. In the northwest corner rocks of this unit are clearly extrusive, as fragments of rhyolite are present in the adjacent debris flow.

Gabbroic dykes, probably of several generations, cross-cut all the rock units in the area excluding the dacite dykes and the Phantom Lake Granite. Both plagioclase phyric and aphyric types are present. Some are obviously feeders for the overlying flows; however, others also cross-cut the Boot Lake Pluton. These latter dykes are narrow, equigranular and fine grained.

The Boot Lake Pluton is a complex multiphase body ranging in composition from gabbro to granodiorite but is composed mostly of massive grey diorite and granodiorite. The north-central basalt-diorite contact is a fault contact. Here, for 70 m inward from the margin, the pluton is extremely fractured and partially silicified, with most fractures coated with ankerite. Where the pluton has an intrusive rather than fault-controlled contact, several intrusive phases are evident. The most common is a medium-grained, massive, equigranular amphibolite (metagabbro). Massive quartz diorite also occurs. Porphyritic dioritic dykes, with large round quartz phenocrysts (up to 7 mm) and plagioclase phenocrysts (5 mm) cut the border zone of the intrusion, as do irregular felsic epidote-rich and aplite dykes. Dykes of diorite injected into the basalt become increasingly mafic away from the pluton.

The Phantom Lake Granite occurs as irregular dykes cross-cutting all of the rock units. It comprises large K-feldspar crystals (2 cm) in a medium-grained (1 to 4 mm) matrix of quartz and feldspar and is undeformed.

Structure

The Rio Fault strikes at about 040° and dips steeply west. To the northeast and southwest of the mineralized area it appears as a narrow (5 m) zone of intense shearing and deformation. Northwest of the mineralized zone there is little alteration and shear planes are coated with chlorite and ankerite, whereas to the southeast intense silicification, ankeritization and abundant quartz veining are characteristic. In the mineralized area there is no single distinct fault surface, but instead a wide (90 m) zone of intense fracturing and alteration. Rocks throughout the map area are cut by minor fractures of several preferred orientations, which are presumed to be associated with the movements on the Rio Fault.

Northwest of the Rio Fault there are generally two preferred orientations; the earlier set (S_1) trends at 090° and dips steeply north, whereas the later (S_2) set strikes at about 025°, dips steeply west and shows a small amount of dextral movement. Near the fault the later fracture set is deformed by small faults (S_3) trending 170° and dipping 60°W. The 025° fractures are drag folded into the 170° faults on axes plunging 60° at 340° (Fig. 1).

Alteration and Mineralization

The gold-bearing pyritic orebodies lie within a wide zone of silicic-ankeritic (chert-carbonate) alteration along the Rio Fault. Within the silicic alteration, ankerite is disseminated and also occurs as narrow (2 cm) veinlets of massive ankerite which, in at least one place, are folded.

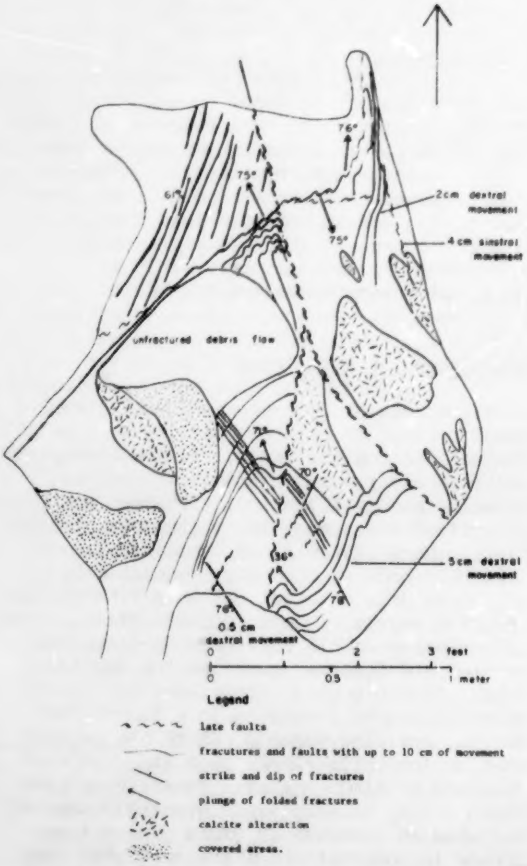

Figure 1 - Geological sketch of an outcrop located at 1+80 S, 4+40 E. The entire outcrop is coarse debris flow, extremely fractured and containing patches of calcite alteration. The fracture patterns on this outcrop illustrate the movement on the various fractures and their relationships to each other.

The basalts are most intensely altered, although in some places amygdules and other volcanic features can still be recognized. Near the edge of the alteration zone lenses of massive chert replace basalt along discrete fractures.

Diorite is also strongly altered but retains its texture such that nebulous plagioclase pseudomorphs can still be identified. The Phantom Lake Granite becomes bleached and ankeritized by the alteration.

In the northern part of the alteration zone veins of massive white quartz are present along its southeastern edge. Trenches in the southern part of the zone contain massive white quartz veins.

Chert-carbonate alteration also occurs along minor parallel fractures in both the hanging wall and footwall of the Rio Fault, outside of the main alteration zone.

While the alteration associated with the mineralization is obvious and easy to trace, the pyrite-gold mineralization is less evident on surface. Discrete bands with disseminated, very fine grained pyrite aggregates occur within the chert-carbonate rock. Gold is present as very small blebs within or between pyrite grains and as discrete particles around pyrite aggregates. Other minerals noted are galena, sphalerite and chalcopyrite.

Underground the relationship of mineralization to alteration and stratigraphy seems to indicate two types of mineralization (P. Master and C. Moore, pers. comm.). The 'hanging wall' mineralization forms bands of bedded aspect and lenses with up to 15 percent disseminated pyrite in the fine-grained chert-carbonate alteration. Mineralization of this type contains from 1.4 g/t (.05 oz./ton) to 4.25 g/t (.15 oz./ton) Au. The 'footwall' mineralization comprises fine- to medium-grained (1 to 5 mm) pyrite aggregates commonly associated with fractures, veins of silicification and rarely quartz veins. This type of mineralization can assay up to 100 g/t but more commonly grades around 34 g/t (1 oz./ton) over a few tens of centimeters. The hanging wall type of mineralization generally trends at about 025° and the footwall type at about 170°.

Discussion

The following factors appear most relevant to any discussion of ore controls in the Rio deposit:

1) North and south of the mineralized zones the Rio Fault is a narrow (5 m) shear zone with a well-developed shear fabric. In the area of mineralization a discrete shear plane is absent and replaced by a wide (90 m) zone of alteration and deformation.

b) Several generations and orientations of fracture are present in the alteration zone.

c) The wide zone of alteration and mineralization appears to be confined to that part of the Rio Fault where basalt has been brought into contact with basalt.

The Rio Fault, which regionally trends northeasterly (020° to 045°), parallel to the S_2 minor fracture set, in general forms the contact between basalt and the Boot Lake Pluton. However, in the area of alteration and mineralization, a small inlier of basalt on the footwall of the Rio Fault is brought into contact with basalt on the hanging wall. Differing rheological properties of the footwall basalt and granodiorite will, during evolution of the fault, have led to rotation of the stress field in the proximity of the basalt inlier. In order to resolve this rotational component, two rather than a single set of fractures developed, at 025°

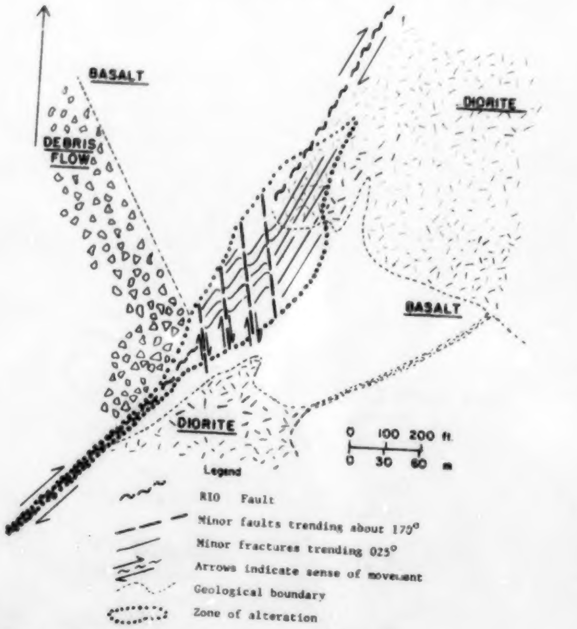

Figure 2 - Geological sketch illustrating a possible interpretation for the formation of the minor structures measured throughout the area, the formation of the alteration zone and the fractures which control the orientation of the ore zones.

and 170° respectively. The former (S_2) recorded the main movements on the fault, while the latter (S_3) resolved the rotational component. The dominant fractures became drag folded by those at 170° (S_3) (Fig. 2). In this way a wide zone of fracturing and thence porosity was provided for access of any hydrothermal fluids. The mineralization is of two types: the low-grade 'hanging wall-type', which is relatively pervasive throughout the alteration zone, and the high-grade 'footwall-type', which appears to be controlled by the S_3 fractures. In harmony with the evolving fracture pattern, the 'hanging wall' mineralization was probably introduced at an early stage and reworked to yield the higher grade 'footwall' mineralization along S_3 fractures. If this scenario is correct, one would expect to find other zones of 'footwall-type' mineralization trending at 170°, parallel to the zone already outlined by underground work.

Acknowledgments

I wish to acknowledge the cooperation of Mr. C.A.L. Hogg and Mr. L. Hogg of Flin Flon Mines in allowing access to the mine property, and C. Moore and P. Master for discussions and insights into the orebody at depth.

References

Byers, A.R., Kirkland, S.J.T. and Pearson, W.J. (1965): Geology and mineral deposits of the Flin Flon area; Sask. Dep. Miner. Resour. Rep. 62.

Pearson, J.G. (1979): Flin Flon gold prospects; in Summary of Investigations 1979, Sask. Geol. Surv., Misc. Rep.79-10, p145-151.

____________ (1982): Gold metallogenic studies: Amisk Lake east area; in Summary of Investigations 1982, Sask. Geol. Surv., Misc. Rep.82-4, p64-70.

____________ (1983): Gold metallogenic studies: Flin Flon - Amisk Lake area; in Summary of Investigations, 1983, Sask. Geol. Surv., Misc. Rep.83-4, p67-74.

Stockwell, C.H. (1960): Flin Flon - Mandy area, Manitoba and Saskatchewan; Geol. Surv. Can., Map 1078A (with descr. notes).

Project 8405

Mineralized Core Collection

by A.J. Gracie

Gracie, A.J. (1984): Mineralized core collection; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The Saskatchewan Energy and Mines mineralized core collection comprises mineralized and geologically important drill cores from northern Saskatchewan. It is housed primarily in La Ronge in a 23 by 22 m warehouse attached to the Precambrian Geological Laboratory. Steel core racks provide storage for some 53,000 m of complete and condensed cores, filling about 50 percent of warehouse capacity. A core examination room attached to the administrative office of the laboratory has a core splitter, rock saws, microscopes and all equipment required for detailed examination of the core. A small, interim storage facility is also maintained in Denare Beach by the resident geologist's office in Creighton.

A core collection program was started by the department as early as 1965; however, the decision to concentrate on mineralized and geologically important cores was not made until 1977. Since that time, with the co-operation of the mining industry, an excellent non-confidential selection of cores from uranium deposits in northern Saskatchewan has been assembled. Base metal and gold properties are also represented in the collection, although not as strongly as uranium. Non-confidential diamond-drill hole location maps, logs and assays support and illustrate all cores stored in the laboratory. Whenever possible, core from individual holes, or cross-sections of holes, across deposits which have been described in the literature have been acquired.

In addition to the core collection, there are suites of hand samples from a large number of mineral properties in northern Saskatchewan.

During the past year, Saskatchewan Energy and Mines acquired the cores listed in Table 1. Because the department's Uranium City office is now closed, a small amount of concentrated core, largely from mineral prospects

Table 1 - Core Acquisitions, September 1, 1983 to August 31, 1984

Company/Exploration Commodity	NTS	Number of Holes	Core Size	Property/ Deposit	Meterage
Giant Yellowknife Mines Ltd./Au	64-D-4-NW 64-D-5-SW	1	BQ	ML 5337, ML 5336/ Wedge Lake, Twin zone	73 m
Goldsil Mining and Milling Inc./Au	74-A-1-SW	1	NQ	Jolu Mallard Lake	37.4 m
Key Lake Mining Corporation Ltd./U	74-H-4	10 (concentrated holes	BQ	ML 5205/Deilmann orebody, section 11+900 E	(43 boxes represent 1112 m of core)
Rex Silver Mines/Au	64-D-6-SW	4	BQ	CBS 5497	328 m
Saskatchewan Mining Development Corp./U	74-I-8	2	NQ	CBS 4728/Dawn Lake zones	272 m
Scurry Rainbow Oil and Gas Ltd./Ni	73-P-15-SW	1	Axt	ML 5164/ Gochagar Lake	342 m
Marline Oil Ltd./U	74-F-13	1	NQ	CBS 5192 Shiels Lake	471.65 m

evaluated in the first Saskatchewan uranium boom in the fifties, has been transferred to La Ronge.

A new core inventory is in preparation to assist use of the core collection by the mineral exploration industry. The new inventory identifies the location of all the drillholes by latitude and longitude and on 1:250,000 scale maps, and gives full particulars of each hole (company, mineral disposition, exploration commodity, year, hole number, core size, hole bearing and inclination, meterage of sample core, reference to other available exploration data and storage location). This new inventory will be available for general distribution in early 1985.

Gold Metallogenesis and Lithogeochemistry, Flin Flon and Waddy Lake Areas

by Michel Mellinger[1]

Mellinger, M. (1984): Gold metallogenesis and lithogeochemistry, Flin Flon and Waddy Lake areas; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

The Saskatchewan Research Council has initiated projects on gold metallogenesis and lithogeochemistry in the Flin Flon and La Ronge greenstone belts. The objective of these projects is to obtain a better understanding of the genesis of gold mineralization, and to develop lithogeochemical criteria that would be useful for mineral exploration. The projects will be carried out in close cooperation with the Saskatchewan Geological Survey and industry. The location of the four properties visited and sampled this summer is shown on Fig. 1. A brief summary of field observations is given here. The first formal results of this work should be published during late spring 1985.

Flin Flon Area

In the Flin Flon area, work was carried out in the Rio mine, opened recently by Flin Flon Mines Ltd. Sampling was done on the 75-foot level with complementary sampling of drill core. Detailed surface geological mapping of the Rio zone has been carried out by Pearson (this volume).

Gold mineralization in the Rio zone lies adjacent to the northeasterly trending Rio

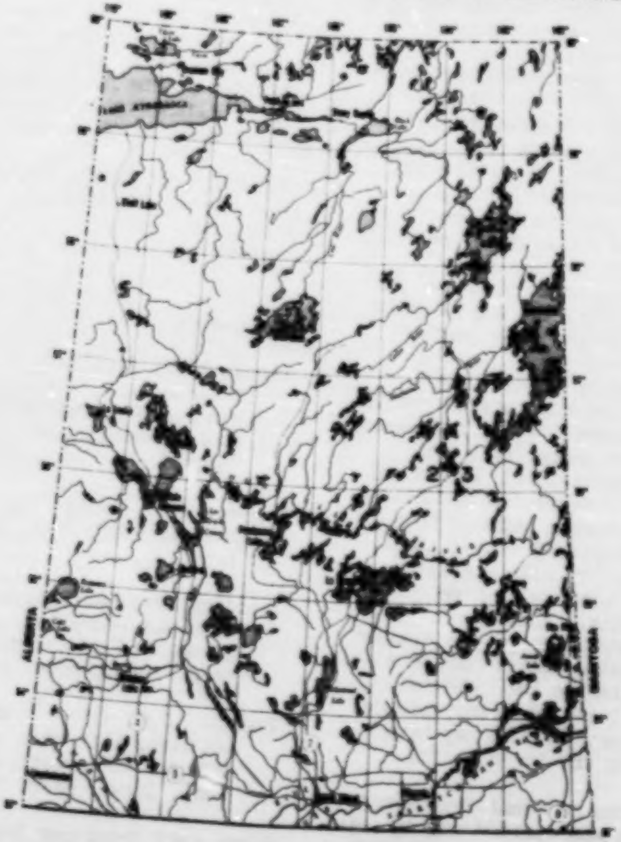

Figure 1 - Location of gold properties sampled: (1) Rio mine; (2) Waddy Lake; (3) Weedy Lake; (4) Wedge Lake.

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[1] Resources Sector, Saskatchewan Research Council, Saskatoon.

Fault within intensely silicified rocks comprising mafic metavolcanics and cross-cutting dykes of Phantom Lake granite. Silicification also affects the dykes in the alteration envelopes. Gold occurs in pyritic fractures and veins as very fine grained blebs either within pyrite, in contact with pyrite or closely associated with it (Byers et al., 1965; Pearson, 1983). The structure of the Rio zone is complex and will require detailed analysis before the nature of the structural controls on mineralization can be established.

La Ronge Belt

In the La Ronge greenstone belt, work focused on three properties in the Waddy Lake area: Waddy Lake, Weedy Lake and Wedge Lake.

At Waddy Lake (operated by Waddy Lake Resources Inc.), sampling of drill core was carried out in one cross-section of the Komis deposit. Rocks encountered in drill core are meta-andesite, metarhyolite, granodiorite dykes and quartz veins. The andesite appears to be affected by contact metamorphism, probably due to the granodiorite body encountered at depth in some drillholes (see also Johnston, 1981). Gold mineralization is encountered within pyritized andesite and in quartz veins, and may be visible in hand specimen in the latter case. Pyritization primarily affected the andesite, and gold mineralization is thus essentially confined to the mafic rocks (Waddy Lake Resources Inc., 1983). The pyrite is usually idiomorphic and commonly shows pressure shadows of quartz; however, the associated deformation is slight in the area sampled.

At Weedy Lake (operated by Golden Rule Resources Ltd.), sampling was carried out in drill core mostly from the B zone, but also from the A zone. Rocks encountered are predominantly meta-andesite, metadacite and granodiorite, and are intersected by shear zones containing some quartz veins. Gold mineralization is encountered within the shear zones in association with pyritized host rocks and may be visible in hand specimen in quartz veins. Thus the mineralization at Weedy Lake appears similar in nature to that at Waddy Lake. The A zone, where pyritized diorite has been sheared extensively during a later shearing episode, is a possible exception, as gold may have been introduced during the later event.

At Wedge Lake (operated by Giant Yellowknife Mines Ltd.), sampling was carried out on core from two drillholes which intersect sulphide facies iron formation. Gold mineralization occurs disseminated within a cherty sulphide iron formation containing about 75 percent combined pyrite and pyrrhotite, 2 percent pyrite and locally some magnetite. Iron formations in the same general area were described by Harper (1983). Gold mineralization here is different from that of the two properties mentioned above and may be of the volcanic exhalative type.

Acknowledgments

The author wishes to thank John Pearson (Saskatchewan Energy and Mines, Creighton) for his cooperation in organizing work in the Flin Flon area. Flin Flon Mines Ltd. is gratefully acknowledged for permission to sample at the Rio mine; I wish to thank V. Hogg Jr. for his encouraging attitude, P. Master for his cooperation and C. Moore for his guidance at the mine site and in underground workings. Many thanks to Ron Netolitzky (Golden Rule Resources Ltd.) for making fieldwork in the Waddy Lake area possible and for his guidance on the Weedy Lake property. J. Zimmerman (Waddy Lake Resources Inc.) kindly provided all necessary information about the Waddy Lake property; A. Ransom (Giant Yellowknife Mines Ltd.) arranged access to the Wedge Lake property; and R. Allan (Taiga Consultants Ltd.) assisted during fieldwork.

Last, but not least, effective and efficient help during all fieldwork was provided by Bill Smith, whose on-going support has been greatly appreciated.

References

Byers, A.R., Kirkland, S.J.T. and Pearson, W.J. (1965): Geology and mineral deposits of the Flin Flon area, Saskatchewan; Sask. Dep. Miner. Resour., Rep. 62.

Harper, C.T. (1983): Iron ores of northern Saskatchewan; Sask. Energy Mines, Rep. 220.

Johnston, W.G.Q. (1981): Gold metallogenic studies: Waddy Lake and region; in Summary of Investigations 1981, Sask. Geol. Surv., Misc. Rep. 81-4, p92-96.

Pearson, J.G. (1983): Gold metallogenic studies: Flin Flon - Amisk Lake area; in Summary of Investigations 1983, Sask. Geol. Surv., Misc. Rep. 83-4. p67-74.

Waddy Lake Resources Inc. (1983): Annual Report, 1983.

RESIDENT GEOLOGIST REPORTS

Mineral Exploration Activity in the La Ronge and Athabasca Mining Districts

by A.J. Gracie

Gracie, A.J. (1984): Mineral exploration activity in the La Ronge and Athabasca Mining Districts; *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

Uranium exploration expenditures declined last year, although at a reduced rate. The eastern part of the Athabasca Basin and the Carswell Dome were the principal areas of activity. Cogema Canada Ltd. has announced spectacular grade and reserve figures for the Waterbury property, lending encouragement to drilling programs around the uranium mining areas. Very little work was carried out in the centre of the Athabasca Basin or along its northern and southwestern margins. Exploration will likely remain at a fairly constant level over the next few years and be concentrated in the Wollaston, Key Lake and Carswell Dome areas.

Cluff Mining Ltd., owned jointly by Amok Ltd./Ltee. (80 percent) and the Saskatchewan Mining Development Corporation (20 percent), has completed Phase I of the mining program begun in 1981 at their Cluff Lake property. Gravimetric residues from the ore of the open-pitted, high-grade (6 percent U) D-zone orebody have now been processed. Phase II milling has begun. This second phase will involve primarily underground mining of lower grade (0.4 percent U) ores from several zones. Annual production capacity will be close to 1 million kg U. A 15-year mine life is anticipated for Phase II at current reserve levels.

Eldor Mines Ltd. has finished mining the Rabbit Lake orebody; however, the mill is still processing stockpiled ore while undergoing modification to accommodate geochemically more complex ore from the Collins Bay 'B' zone. In the pit itself, which will serve as a future tailings disposal site, a drift and raise have been completed to allow tailings dewatering. At the Collins Bay 'B' zone, the dyke which will hold back the waters of Wollaston Lake from the proposed open pit is near completion and stripping of overburden from the pit area is underway. The first ore from the 'B' zone will likely be mined early in 1985 and milling should commence toward the end of the year. Current annual production at Rabbit Lake is around 1.5 million kg U, down from peak levels of over 2 million kg U when somewhat higher grade ore from the Rabbit Lake pit was being processed. Collins Bay 'B' zone production will be at a similar rate of around 2 million kg U from ore grading 0.38 percent U. Reserves in the zone are estimated at 12,000 t U.

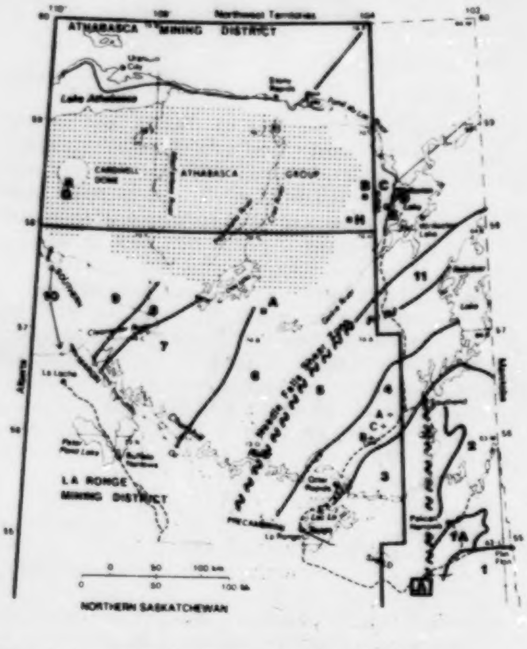

Figure 1 - Location of the La Ronge and Athabasca Mining Districts in relation to geological domains in the Precambrian Shield. Numbered domains: (1) Flin Flon; (1A) Hanson Lake Block; (2) Kisseynew; (3) Glennie Lake; (4) La Ronge; (5) Rottenstone; (6) Wollaston; (7) Mudjatik; (8) Virgin River; (9) Western Craton; (10) Clearwater; (11) Peter Lake.

Current uranium mines, potential mines and major exploration locations related to the Athabasca Basin (indicated by ■): (A) Key Lake Mining Corporation, Key Lake; (B) Canada Wide Mines Ltd., 'Midwest Lake'; (C) Saskatchewan Mining Development Corporation, Dawn Lake joint venture; (D) Eldor Mines Ltd., Collins Bay and Eagle Point zones; (E) Eldor Mines Ltd., Rabbit Lake; (F) Canadian Occidental Petroleum Ltd. - Inco Ltd., McClean Lake joint venture; (G) Cluff Mining Ltd., Cluff Lake; (H) Cogema Canada Ltd., Waterbury Lake joint venture. Shading represents interior area where the Athabasca Group exceeds 500 m in thickness.

Current gold exploration locations (indicated by +): (A) Golden Rule Resources Ltd., Wedge, Weedy and Greenhill occurrences; (B) Starrex Mining Corporation Ltd. - Saskatchewan Mining Development Corporation, Star Lake joint venture; (C) Waddy Lake Resources Inc. - Energy Reserves Canada Ltd., Komis and EP zones; (D) Sulphide Lake area; (E) Anglo-Rouyn Mine (closed).

Current base metal exploration locations (indicated by ▣): (A) Granges Exploration AB, Bigstone Lake area.

Mining and milling of the Gaertner orebody at Key Lake commenced in 1983 with output of the first yellowcake on October 20. Production in 1983 was 423,000 kg U and the target for 1984 is around 4 million kg. Designed production capacity of 4.6 million kg U should be achieved in 1985. The Key Lake mine comprises two orebodies, the Gaertner and the Deilmann, both of which are accessible by open-pit methods. These orebodies, together with fluvioglacial cobble ore from the Deilmann, contain an estimated 75,000 t U at a grade of 2 percent U. The mine is operated by Key Lake Mining Corporation, which is owned by the Saskatchewan Mining Development Corporation (50 percent), Uranerz Exploration and Mining Ltd. (33.33 percent) and Eldor Resources Ltd. (16.67 percent).

Several deposits in the Athabasca Basin are awaiting development, including those at Midwest Lake, Dawn Lake and McClean Lake, as well as the several orebodies additional to the 'B' zone in the Collins Bay - Rabbit Lake area. However, these are overshadowed by the massive Cigar or Waterbury Lake deposit. This deposit, jointly owned by the Saskatchewan Mining Development Corporation (50.75 percent), Cogema Canada Ltd. (33.625 percent), Idemitsu Kosan (11.875 percent) and Corona Grande (3.75 percent), is located between Key Lake and Rabbit Lake. It was found in 1981 and is now undergoing predevelopment studies to determine in more detail the thickness and grade of ore, to acquire environmental base-line information and to establish the parameters necessary for mining. Uranium reserves are currently estimated at approximately 90,000 t U at an average grade of 8.5 percent U (Lloyd 1984). Roughly 70 percent of these reserves are drilled indicated; the remaining 30 percent are inferred reserves. The Cigar Lake deposit lies below Athabasca Group sandstones at a depth of 410 to 440 m.

Although there is as yet no gold production from the Glennie Lake and La Ronge Domains, gold exploration activity has increased in these areas over the last year. In March 1984, the Saskatchewan Government announced the Mineral Industry Recovery Program, an incentives package comprising tax benefits, regulatory changes and geoscience support, which will assist in the development of Saskatchewan's gold and base metal potential.

Junior mining companies and the Saskatchewan Mining Development Corporation dominate gold exploration in the La Ronge and Glennie Lake Domains, although an increasing interest among major private mining establishments is now apparent. The use of new techniques such as biogeochemistry, overburden drilling and NQ wireline drilling for improved recovery and sampling give this effort a better chance of success than the first gold exploration thrust some forty years ago.

Exploration for base metals has not increased since last year and the Bigstone Lake deposit of Granges Exploration AB and the Saskatchewan Mining Development Corporation is the only new discovery made to date.

Three major all-weather highways, to Rabbit Lake, Cluff Lake and Key Lake, now give access to northern Saskatchewan and major improvements to Highway 106 make travel to Flin Flon from La Ronge or Prince Albert much faster.

Uranium

Athabasca Group Perimeter:

Exploration drill programs concentrated on the detection of conductor- and/or fault-related unconformity deposits using the Key Lake model as a basis. Properties with active drill programs in the perimeter zone lie between Stony Rapids and Key Lake. Two programs focused on a regional extension of the Collins Bay Thrust Zone to the southwest of Collins Bay. Cogema Canada Ltd. operated the Waterbury joint venture.

Exploration is clearly more difficult and costly in the deeper part of the Athabasca perimeter area. However, this has not discouraged all companies from attempts to define and drill test favourable geology and conductors in the basement with fences of holes. Radioactive boulders in one area have led to recognition of fault-related drill targets in the sandstone and conductor-related targets in the metamorphosed basement. Identification of clay minerals, alteration, bleaching and trace element haloes has also proved valuable in target selection.

Athabasca Group Interior:

Exploration methods are the same as those used in the deeper part of the perimeter area. Last year only one drill program, a joint venture at Read Lake operated by Kerr Addison Mines Ltd., attempted to test basement targets for uranium in the Athabasca Group interior.

Crystalline Basement:

In general, companies have continued to show little interest in uranium exploration outside the Athabasca Basin, although mineralization is known at some considerable depth below the sub-Athabasca Group unconformity (e.g. the Eagle Point deposit in Collins Bay). However, Minatco is actively exploring their Wollaston Lake Fife Island property which may lie on a northeasterly extension of the Collins Bay Fault Zone.

Gold

La Ronge Domain:

The 21 and EP zones are new gold discoveries in the La Ronge Domain. The 21 zone on the Starrex Mining Corporation Ltd. - Saskatchewan Mining Development Corporation joint venture property (ML 5118) has a 79.2 m strike length and ranges in width from 1.5 to 14.3 m (Northern Miner, May 24, 1984). Preliminary drill-indicated reserves are estimated at 208,653 t grading 17.1 g/t (0.5 oz./ton) Au to a depth of 190.5 m at a cut-off grade of 3.4 g/t (0.1 oz./ton) Au (Northern Miner, July 12, 1984). The 21 zone forms a tabular elongate lens of mineralization which is subvertical and plunges at 55° to the southwest. A Saskatchewan Mining Development Corporation news release (February 20, 1984) described the gold mineralization as associated with late-phase mafic dykes and quartz injected into northeast-trending shear zones within the Star Lake granodiorite.

The EP or Eric Partridge zone occurs a little to the north of the previously delimited Komis deposit at Waddy Lake. Here a Waddy Lake Resources Inc. - Energy Reserves Canada Ltd. joint venture has found gold in a shallow dipping, 3 to 7 m thick zone of shearing and quartz veining flanking an intermediate dyke (Asbury and Zimmerman, 1984). Andesites form the hanging wall and footwall of the zone. Gold occurring in tills to the south of the EP zone provided the initial clue to this discovery. An overburden drilling program to delimit the dispersion train identified some extremely high grade (ca. 34 g/t (1 oz./ton) Au) till sections and led to targetting, diamond drilling and discovery of the EP zone.

Other exploration in the La Ronge Domain is based on old work by Cominco Ltd., Eric Partridge and the Studer family. Goldsil Mining and Milling Inc. has retested showings on the easterly trending Byers Lake Fault and, through Mahogany Minerals Resources Inc., has been redrilling the old Decade Development Ltd. Mallard Lake Mine, originally a Cominco property. The Byers Lake Fault, which continues further to the west than previously thought, is considered a high-potential gold exploration target.

Golden Rule Resources Ltd. and their partners have made significant attempts to upgrade the Weedy, Wedge and Greenhill properties in the Waddy Lake area. The Weedy Lake B zone is related to a shear zone in granodiorite and contains an estimated 1 million t grading 4.5 g/t (0.13 oz./ton) Au or 3.63 million t grading 2.1 g/t (0.06 oz./t) Au (Northern Miner, June 21, 1984). Two additional higher grade zones of mineralization have been identified (A and C zones) and drill tested. The Wedge Lake zone occurs in complexly folded, banded iron formation and has estimated reserves of 600,000 t grading 5.1 g/t (0.15 oz./ton) Au.

The northeast part of the Lac La Ronge Provincial Park is again open for mineral exploration. The Saskatchewan Mining Development Corporation is re-evaluating the Studer A and B zones as part of a broader exploration program in the Sulphide Lake gold camp. These zones have been described as being in or adjacent to lean iron formation in argillite (Coombe, 1983). Noranda Exploration Co. Ltd. has optioned the old Anglo-Rouyn Mine property from a local La Ronge syndicate. This deposit, which was mined for copper, also produced a significant amount of gold at a recovery grade of 1.4 g/t (0.04 oz./ton) and could still have significant gold reserves in the hanging wall.

Glennie Lake Domain:

The level of exploration for gold in this domain has escalated dramatically. Carina Mineral Resources Corp. has drilled the Siskin gold prospect south of Brownell Lake. Currie Rose Resources Inc. tested targets for gold immediately northeast of Laonil Lake, where Claude Resources Inc. acquired Cominco Ltd.'s Seabee prospect. Claude Resources estimates (company release, May 24, 1984) that Seabee's proven, probable and possible reserves to a vertical depth of 304.8 m are 1.01 million t grading 18.2 g/t (0.53 oz./ton) Au uncut, or 11.0 g/t (0.32 oz./ton) Au cut to 34 g/t (1 oz./ton) over an average 2.68 m width. The company has begun a $1.4 million feasibility work program. Claude Resources also states that the gold mineralization is stratabound within metavolcanic and metasedimentary rock sequences. A new permit taken out by the same company covers an extension of the Pitching Lake volcanics.

Other Areas:

The level of gold exploration in the Athabasca Mining District is low. The

Saskatchewan Mining Development Corporation drilled on surface close to the old Frontier adit north of Goldfields. The Corporation also took out a new mineral permit over the Ennadai Lake volcanic belt which crosses the northern provincial boundary into the Northwest Territories.

Base Metals

The level of interest in exploration for base metals has declined slightly in the last year despite the strong play in the south part of the Glennie Lake Domain based on the Granges Exploration AB Bigstone Lake find.

References

Asbury, B.C. and Zimmerman, J.R. (1984): The Komis deposit and the EP zone, Waddy Lake area, Saskatchewan; unpubl. paper presented at Prospectors' and Developers' Assoc. Convention, Toronto.

Coombe, W. (1983): Gold in the La Ronge Domain, Saskatchewan: distribution, character and potential; CIM Bulletin; v76, no851 p80-81.

Lloyd, R.E. (1984): Western Canada uranium perspective; unpubl. paper presented at Internat. Nuclear Conf., Saskatoon.

Mineral Exploration Activity in the Reindeer Mining District

by J.G. Pearson

Pearson, J.G. (1984): Mineral exploration activity in the Reindeer Mining District, *in* Summary of Investigations 1984, Saskatchewan Geological Survey; Saskatchewan Energy and Mines, Miscellaneous Report 84-4.

Mineral exploration activity in the Reindeer Mining District remained at a uniform level as exploration companies continued to search for base metal and gold deposits. The discovery of a new gold zone 9 km east of the Manitoba-Saskatchewan border by Granges Exploration AB and Aberford Resources, sparked a major staking rush in Manitoba; however, as yet the on-strike extension of these rocks into Saskatchewan has received little attention.

Flin Flon Mines Ltd. began production of the Rio zone, 5 km south of Creighton, during July. An official opening ceremony was held on August 30.

During the year, one permit of 551.76 km^2 (126,340 acres) was taken out, as well as 407.45 km^2 (100,682 acres) in claims and claim blocks. Of this total, 32 percent was in the La Ronge Domain, 31 percent in the Wollaston Domain, 30 percent in the Flin Flon Domain and 7 percent in the Glennie Lake and Kisseynew Domains. This compares with 1983 figures of 3856.47 km^2 in permits and 411.16 km^2 in claims and claim blocks. During the past year 5437.32 km^2 (1,343,616 acres) in permits, claims and claim blocks lapsed.

Gold

At Flin Flon Mines' Rio deposit, underground development is continuing on the 23 m (75-foot) and 41 m (135-foot) levels. One small zone, the '2700 stope', has been mined out above the 23 m level. Nearby, Flin Flon Mines also carried out an 18-hole, 453.8 m drill program to evaluate a quartz-sulphide-gold showing called the Cor occurrence.

Hudson Bay Exploration and Development Co. Ltd. (HBED) undertook a gold exploration program in the Nistoassini Lake area during the past summer. This program consisted of a 31 km magnetometer survey, soil and rock geochemistry and geological mapping.

Kenergy Resources Corp. conducted a soil geochemistry program on CBS 3150, to the southwest of the Rio deposit. The

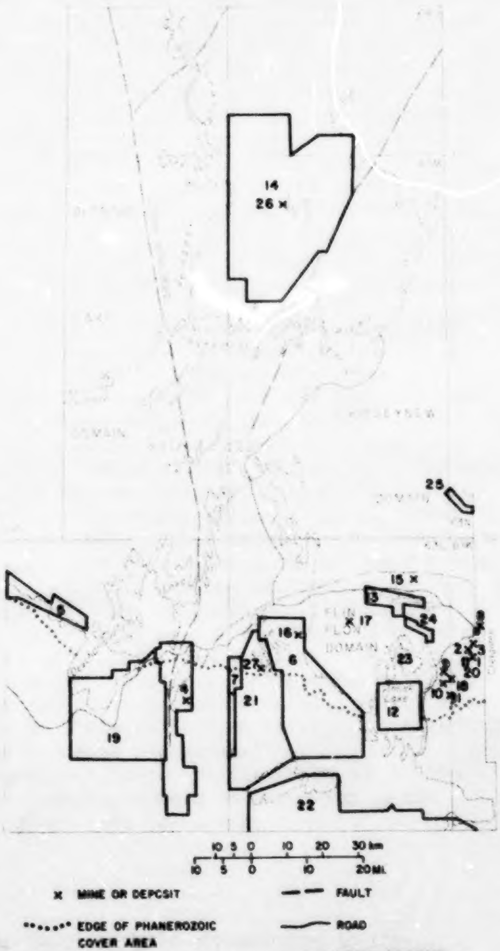

Figure 1 - Location of the southern part of the Reindeer Mining District showing present and past producing mines, deposits and areas of active exploration and development. Areas designated by operator of the project only: Esso Minerals Canada, Deschambault Lake (1); Flin Flon Mines Ltd., Rio mine (1), Newcor mine (2), Cor occurrence (3); Granges Exploration AB, Bigstone deposit (4), Oskikebuk volcanic belt (5), MPP 1138 (6), Chisolm Lake (7); Hudson Bay Exploration and Development Co. Ltd., Flin Flon mine (8), Flexar mine (9), Birch Lake mine (10), Coronation mine (11), Amisk Lake (12), Annabel Lake (13), Gilbert and Pauline Lake (14), Tyrell Lake zone (15), Mal zone (16), Abbot Lake zone (17), Alf zone (18); Ice Station Resources, MPP 1136 (19); Kenergy Resource Corporation, CBS 3150 (20); Saskatchewan Mining Development Corporation, Hanson Lake area (21), Suggi Lake area (22), West Amisk Lake (23), Wolverine Lake (24); Wapa Minerals Ltd. (25); A.L. Parres Ltd., Mokoman Lake deposit (26); Western Nuclear Mines Ltd., Hanson Lake deposit(27).

Saskatchewan Mining Development Corp. (SMDC) continued to evaluate the gold potential of the north Amisk Lake area. In the West Channel of Amisk Lake, nine holes were drilled to test geological and geophysical targets, and 20 km of gradient array IP and 35 km of Apex EM and magnetometer work were completed, together with regional geochemical, geological and biogeochemical surveys.

In the Wolverine Lake area SMDC was active in three programs. On CBS 3206 four holes (420 m) were drilled to test potential gold-bearing horizons outlined by previous geochemical, geophysical and geological surveys. A 15 km gradient array IP survey was conducted and three holes (247 m) put down on the SMDC - Granges Exploration AB joint venture properties, and a further two holes (140 m) were completed on the SMDC - Suneva Resources Ltd. joint venture property.

During the past year Wapa Minerals Ltd. and Comaplex Resources International Ltd. acquired a small gold property in the Mari Lake area. Exploration on this property during the past summer consisted of 15 km of magnetometer and VLF-EM, geological mapping and stripping, with detailed geological mapping and channel sampling of the stripped area.

Base Metals

Esso Minerals Canada optioned three claim blocks from Win-Eldrich Mines Ltd. and A.L. Parres Ltd. Three drillholes totalling 247 m tested anomalies located last winter.

Granges Exploration AB again maintained a very active exploration program in the Flin Flon area and, in joint venture with SMDC, drilled an additional 3154 m in 13 holes to further evaluate the Bigstone deposit. A downhole Pulse EM survey was carried out to test the down-dip extension of the deposit as well as a possible down-faulted southern extension of the orebody. Published reserves are 3.54 million t grading 2.6 percent Cu and 285,000 t grading 16.1 percent Zn. In the area around the Bigstone deposit, 100 km of Apex horizontal loop EM surveys and 2428 m of diamond-drilling in 24 holes were completed. Granges also carried out 30 km of Pulse EM in areas where the Paleozoic cover is thought to exceed 30 m.

The company was active also in several other areas with completion of the following work: 60 km of Apex horizontal loop EM and a geological survey to evaluate favourable horizons in the Oskikebuk volcanic belt; geological mapping and 330 km of horizontal loop EM in the Lacey Lake and Wapawekka Lake areas; 80 km of Apex horizontal loop EM and four holes (224 m) to test conductors on MPP 1138; a small magnetometer survey and two holes (110 m) in the east Amisk Lake area; and 30 km of Apex horizontal loop EM and one hole (74 m) in the Chisholm Lake area (Fig. 1).

HBED carried out a greatly expanded exploration program during the past year. The following programs were carried out on company-operated joint venture properties: 354 km of Apex horizontal loop EM , 307 km of magnetometer and 1014 m of diamond-drilling in eight holes in the Amisk Lake and Annabel Lake area; and 55 km of Apex horizontal loop EM and 58 km of magnetometer in the Gilbert Lake and Pauline Lake areas. On wholly owned ground in the Flin Flon and Amisk Lake areas 53 km of Apex horizontal loop EM, 18 km of magnetometer, 5 km of VLF-EM and 2767 of diamond-drilling in 14 holes were completed. Some of the drilling tested new anomalies, while the remainder explored known zones of mineralization.

Ice Station Resources acquired MPP 1137 and undertook a program consisting of 168 km of Apex horizontal loop EM, 155 km of magnetometer and two drillholes (281.7 m).

SMDC carried out 124 km of Apex horizontal loop EM, 149 km of magnetometer and 14 km of Pulse EM on six grids in the Hanson Lake area. They also drilled 11 holes (1900 m) to test anomalies. During the past summer a small amount of geological mapping was carried out.

Activity of the Creighton Office

Core collection from many of the ore deposits and subeconomic mineral occurrences continued during the past year. Core from the following gold and base metal mines and occurrences is now stored at an interim storage facility at Denare Beach and is available for examination. The co-operation of the various companies and individuals who have made this material available is gratefully acknowledged.

Gold deposits:

1) Flin Flon Mines Ltd.: Rio deposit and Cor occurrence
2) J. Reid: Bomber Lake occurrence

Base metal deposits:

1) Hudson Bay Mining and Smelting Co. Ltd.: Coronation mine, Flexar mine, Abbot Lake zone, Tyrrell Lake zone, Mal zone (Wakisew Lake area) and Alf zone (Echo Lake area)
2) A.L. Parres Ltd.: Knife Lake zone and Pistol Lake zone

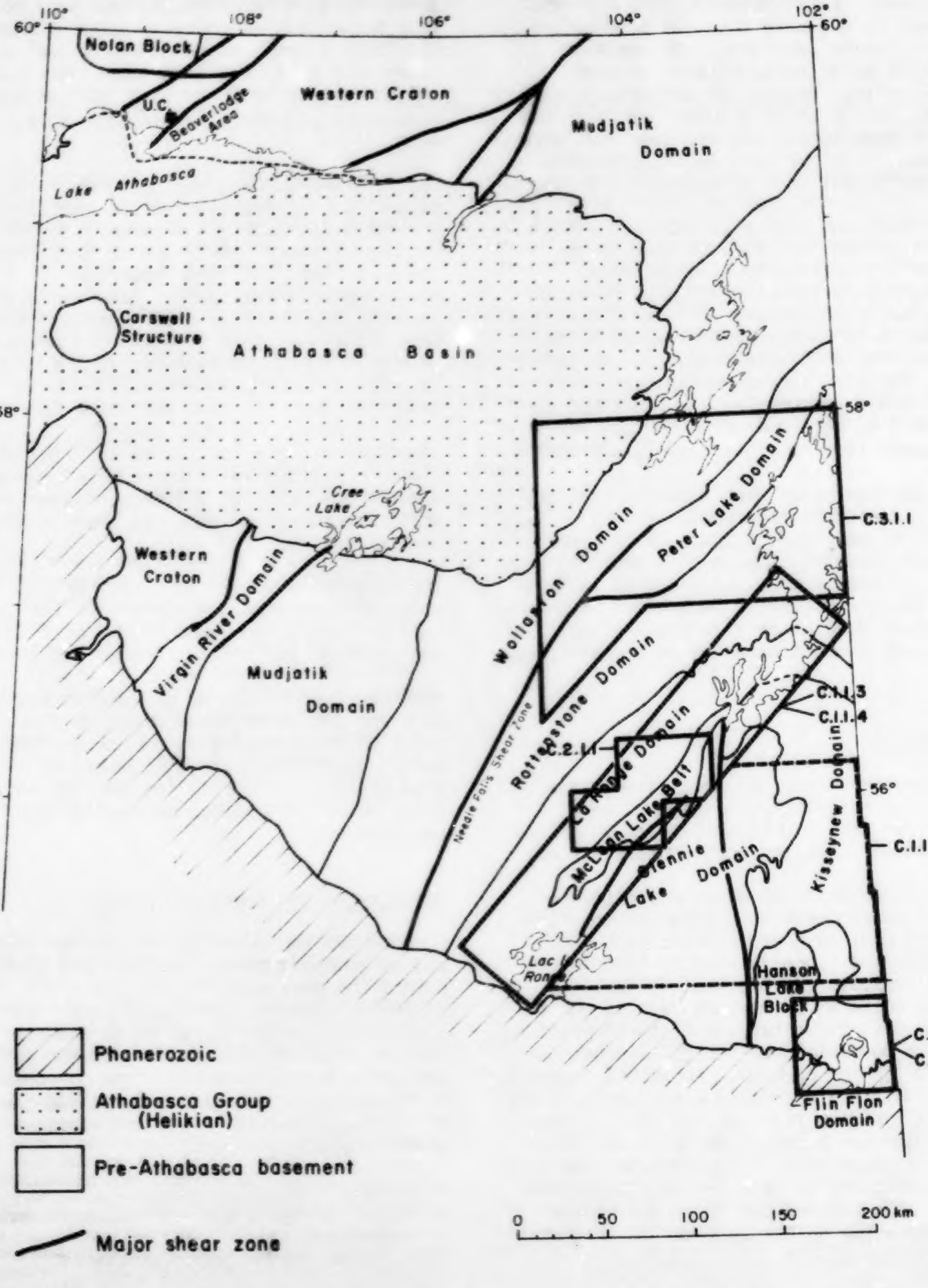
110°
108°
106°
104°
102°
60°
60°
Nolan Block
U.C.
Beaverlodge Area
Western Craton
Mudjatik Domain
Lake Athabasca
Carswell Structure
Athabasca Basin
58°
58°
Cree Lake
Western Craton
Virgin River Domain
Mudjatik Domain
Wollaston Domain
Peter Lake Domain
C.3.1.1
Rottenstone Domain
Needle Falls Shear Zone
C.1.1.3
C.1.1.4
C.2.1.1
La Ronge Domain
McLennan Lake Belt
Glennie Lake Domain
Kisseynew Domain
56°
56°
C.1.1.1
Lac la Ronge
Hanson Lake Block
C.1.1.2
C.1.1.4
Flin Flon Domain
Phanerozoic
Athabasca Group (Helikian)
Pre-Athabasca basement
Major shear zone
0
50
100
150
200 km

Figure 1 - General locations of GSC fieldwork, Canada-Saskatchewan Mineral Development Agreement, 1984. See text for project number key.

Geological Survey of Canada Activities in 1984 under the Canada-Saskatchewan Mineral Development Agreement, 1984-85 (Geoscience Program)

Federal (GSC) activities in the new Saskatchewan five-year Mineral Development Agreement (MDA) commenced during the 1984 field season in subprograms 1 (Mineral Deposit and Geological Investigations) and 3 (Geochemical Surveys). Aeromagnetic surveys of subprogram 2 (Geophysical Surveys) will be conducted in the fall of 1984. Due to the late date of formal implementation of the Agreement (end of March, 1984) and previous field program commitments by the GSC, the 1984 fieldwork was of a reconnaissance nature only. The general areas of work in 1984 are shown in Fig. 1. Full field programs under the Saskatchewan MDA will be underway during the 1985 field season.

Subprogram 1 (Mineral Deposit and Geological Investigations)

Initial fieldwork was conducted under Projects C.1.1.2 (Flin Flon - Amisk Metallogeny), C.1.1.3 (La Ronge Metallogeny Studies) and C.1.1.4 (Metallogeny of Ultramafic and Mafic Rocks).

In the Flin Flon - Amisk Lake belt (C.1.1.2) a four-person field crew (A. Galley, Project Leader) investigated gold and tungsten occurrences on the Saskatchewan side of the belt. Properties mapped and sampled included: Phantom Lake gold mine, McMillan mine (Phantom Lake area), and Rio mine and Douglas tungsten showing (Douglas Lake area). Problems to be investigated in these areas include 1) the relationship of structurally-controlled alteration within the Phantom Lake granite to gold, tungsten, copper and molybdenum mineralization in the Boot Lake granodiorite and surrounding Amisk metavolcanics and 2) the genetic relationship of tungsten and gold mineralization to the Rio Fault in the Douglas Lake area. At Amisk Lake preliminary work was done at the Mitchell and Amisk Syndicate property on the east shore, as well as at the Duplex, Monarch, Amisk Gold Syndicate, Waverly and Sonora properties on the West Channel.

In the La Ronge Belt (C.1.1.3) K.H. Poulsen conducted preliminary field investigations as part of a four-year study of the structure, stratigraphy and alteration characteristics of mineral deposits of the belt. Occurrences considered to be representative of the following deposit types were examined in 1984:

1) stratiform and stratabound gold and base metal mineralization hosted by volcanic rocks,
2) auriferous quartz veins, and
3) mineralization associated with ultramafic plutonic and volcanic rocks.

At the Star Lake gold deposit mylonitic fabrics were identified within the host granitoid intrusion and examined in outcrop and drill core. The morphology of the ductile shear zone which hosts the gold veins was established, and petrofabric studies are planned which will examine shear zone kinematics, vein geometry, alteration characteristics and genetic considerations for this type of deposit.

L.J. Hulbert (C.1.1.4) carried out a preliminary examination of ultramafic rocks at the Rottenstone Mine. More detailed studies of Saskatchewan ultramafic rocks and associated mineral occurrences will be carried out in subsequent years of this project. At present this project is being funded through the GSC A-Base program, but it will be incorporated in the MDA program in subsequent years.

Subprogram 2 (Geophysical Surveys)

Under project C.2.1.1 a contract has been awarded to Kenting Earth Sciences Ltd., Ottawa for a total of 4778 line km of airborne gradiometer surveying in the general Waddy Lake area (parts of NTS 64 D-3,-4,-5,-6 and 74 A-1,-8). Flying commenced in October 1984 and results are expected to be released in the Geophysical Map Series prior to the 1985 field season.

Subprogram 3 (Geochemical Surveys)

Geochemical work in 1984 under Project C.3.1.1 consisted of a program to re-analyze the original GSC 1974 La Ronge lake sediment survey samples for gold. Analyses have been completed and compilation and processing of data are in progress. No follow-up work on this project is planned for 1984-85.

SASKATCHEWAN ENERGY AND MINES REPORTS

Fuzesy, Anne (1984): Index to assessment work in the Athabasca Mining District of Saskatchewan; Saskatchewan Energy and Mines, Miscellaneous Report 84-8, 98p (supplement to Miscellaneous Report 79-5).

Fuzesy, Anne (1984): Index to assessment work in the Southern Mining District of Saskatchewan; Saskatchewan Energy and Mines, Miscellaneous Report 84-6, 26p.

Harper, C.T. (1983): The geology and uranium deposits of the central part of the Carswell Structure, northern Saskatchewan; unpublished Ph.D. thesis, Colorado School of Mines, 605p.

Within the Carswell meteorite impact structure three types of uranium occurrences are recognized: U-Th mineralization in pegmatites and granodiorites; pitchblende vein and unconformity-related deposits of simple and complex mineralogy; and detrital U-Th concentrations in Athabasca Group conglomerates. The pitchblende deposits are the only economically significant deposits. They occur mainly in basement rocks, but also in lower Athabasca Group sediments, are genetically linked, and classed as unconformity-related deposits.

Deposits of simple mineralogy (N, Claude, OP, R, F, A6, and Dominique-Peter) contain uraninite/pitchblende and coffinite accompanied by hematite, and variable, but minor amounts of pyrite, chalcopyrite, galena, jordesite, and carbonaceous material. They are hosted by basement rocks but are not far below the sub-Athabasca unconformity. In addition to the above minerals, deposits of complex mineralogy (D Zone) contain thucholite, native gold and selenium, gold tellurides, sellenides of Pb, Bi, Ni and Co, and minor Ni-Co arsenides. The D Zone occurs at the sub-Athabasca unconformity and is rooted in basement gneiss.

The deposits owe their present configurations to a multistage evolution which generally involved metal precipitation following periods of brecciation. Initial mineralization in the basement consisted of uraninite/pitchblende-base metal sulfides-euthedral quartz veins associated with dark green chloritized shear zones. In places this initial stage was also accompanied by formation of hematite in the wall rocks. At the sub-Athabasca unconformity uraninite/pitchblende precipitated along with base metal sulfides, gold, gold tellurides, selenides and minor arsenides in association with dark green chloritization, which is surrounded by a much broader zone of pale green, magnesium, chloritic and/or sericitic alteration. Subsequent wall rock alteration in the basement consisted of red (chloritic) hematite alteration and pervasive pale green chloritic-sericitic alteration. Silicification and tourmalinization occur locally. The common occurrence in basement-hosted mineralization of pitchblende with red or red brown hematite indicates that coupled oxidation-reduction reactions were important in forming later stages of the deposits.

Lithogeochemical studies indicate that the broad pale green chloritic alteration envelop is characterized by the introduction of Mg and H_2O, along with U, Mo, Au, Cu, Co and As and by the removal of Fe^{3+}, Ca, K, Na, and CO_2, as well as Cr, Sr, Rb, and elemental C. Mineralized rocks are characterized by introduction of Mg, H_2O, total Fe, rare earth elements, U, Mo, Pb, Au, Cu, Co, Ni, As, and Ag. Immediately adjacent to some mineralized structures the major and trace elements are depleted. Uranium provides the best pathfinder, although Mo and Cu may be useful where alteration is more widespread.

Step-wise pyrolysis-gas chromatography analysis of carbonaceous material from the Claude deposit, contains trapped methane and other complex hydrocarbons. Carbon isotopic data indicate that the hydrocarbons have apparently formed from an already depleted ^{13}C source, perhaps graphite.

A diagenetic-hydrothermal model is the preferred explanation for the origin of the uranium deposits in the Carswell area. The model requires the percolation of heated (200° C), oxidizing, metal-bearing brines through the Athabasca Group. These solutions entered the basement along fault and breccia zones where the solutions reacted with graphitic and/or pyritic basement and formed a mobile reductant phase consisting of methane, CO_2, other possible hydrocarbons, and H_2S. Precipitation of pitchblende and the other metals occurred where the mobile reductant mixed with the oxidizing metal-bearing solutions. Fluctuations in the hydrologic regime alternately oxidized and reduced ore and wall rocks, and produced well defined oxidation-reduction fronts. Although local derivation of some metals from wall rocks immediately adjacent to mineralized structures may have occurred, the preferred source of ore constituents is from the Athabasca Group sandstones, by leaching during intrastratal oxidation and diagenetic alteration.

The basement hosted pitchblende deposits, such as the N Zone, are considered to be the remnant root zones of eroded unconformity deposits. Others such as Dominique-Peter are considered deeper extensions of the same.

Johnston, W.G.Q. (1984): Compilation bedrock geology, Reindeer Lake South, NTS area 64D; Saskatchewan Energy and Mines, Report 230 (1:250,000 scale map with marginal notes).

Johnston, W.G.Q. (1984): Geology of the Royal Lake and Laird Lake (east) areas; Saskatchewan Energy and Mines, Open File Report 83-1, 80p.

The Royal Lake and Laird Lake (east) areas (NTS 64D-3 and 63M-14/E), respectively) are along the Reindeer River just south of Reindeer Lake. These areas are underlain entirely by Precambrian rocks, largely by what is designated the Older Gneiss Complex. Some members of this complex, such as the biotitic and amphibole gneisses, lend themselves to differentiation into moderately well defined map units. On the other hand, gneissic granitic rocks are in many localities a mixture of different granites, migmatite and supracrustal rocks, in some localities mapped as the all inclusive migmatite. Typical coarse, migmatitic Kisseynew garnet-biotite-cordierite gneisses containing minor meta-arkose occur along parts of the western and northern margins of the Royal Lake area. These gneisses' stratigraphic thickness is estimated as 750 m. The Kisseynew Gneisses appear to unconformably overlie the Older Gneiss Complex.

The Royal Lake area straddles the main segment of the Tabbernor Lake Fault. Numerous similar parallel faults are also members of this fault system. The apparent association of layered basic intrusives with this fault suggests it may once have been a zone of rifting.

Mineral prospects found to date are of no present economic interest. Small erratic chalcopyrite occurrences have been located along discontinuous fractures in hornblende-rich rocks containing very sparse finely disseminated chalcopyrite. Traces of sphalerite and chalcopyrite, accompanied by considerable pyrrhotite and some pyrite, occur as strata-bound sulphides at widely separated localities, possibly along the same stratigraphic horizon. Traces of chalcopyrite occur in some mafic rocks.

Maps of the Quaternary geology, at the same scale as those for the bedrock geology, accompany the report. Deposits considered part of the Cree Lake Moraine occur in the northern part of the Royal Lake area.

Topographic and character differences between these deposits and the Cree Lake Moraine beyond this area are due to deposition in a prominent low (deeper lake than elsewhere along the Cree Lake Moraine) which was dominated by the discharge of proglacial Reindeer Lake.

MacDougall, D.G. (1984): Metallogeny, Reindeer Lake North, NTS area 64E; Saskatchewan Energy and Mines, Report 239 (1:250,000 scale map with 11p. of descriptive notes).

Saskmont Engineering (1984): Buffalo Narrows Fuel Peat Demonstration Project; Saskatchewan Energy and Mines, Open File Report 84-22, 223p.

This study was conducted by Monenco's Peat Group under contract to Saskatchewan Energy and Mines. It represents the final phase in a series of planned investigations leading to a practical demonstration of fuel peat production and utilization. Although much work remains to be done on all aspects of peat and peatland investigations in the province, it is intended that investigations carried out since 1977 will provide a basis for new work and a stimulus for development of the resource.

Schreiner, B.T. (1984): Quaternary geology of the Precambrian Shield, Saskatchewan; Saskatchewan Energy and Mines, Report 221, 106p.

The Quaternary geology of the Precambrian Shield area of Saskatchewan was studied on a reconnaissance scale for the purpose of providing a data base for mineral and resource exploration and development, as well as for geotechnical studies, land-use planning, and other terrain investigations.

Three distinct types of bedrock occur in the area: (1) Precambrian basement complex, (2) Athabasca Group sandstones, and (3) Phanerozoic sedimentary rocks. The direction of glacial ice flow was mainly from northeast to southwest, with local variations. Ice erosion and deposition were strongly affected by the bedrock. Rugged local relief occurs on the igneous and metamorphic basement rocks which were differentially enhanced as the glacier eroded low-lying areas and polished resistant knobs. A veneer of sandy till can be found in protected areas and a trellis drainage network is developed on the basement rocks. Thick ground moraine of very sandy till, large drumlins, eskers and outwash deposits occurs in the Athabasca Basin as a result of extensive glacial erosion of the nearly flat-lying sandstone. This terrain has a dendritic drainage pattern. On the flat Phanerozoic sands, silts, clays, limestone and dolomite, less sandy material is found in thick till plains and the terrain exhibits a deranged drainage system.

Sections revealing multiple tills, intertill deposits and till over stratified sediments indicate several ice advances. Striations, grooves, roches moutonnées, flutings and drumlins were formed primarily by the last ice advance. As this ice melted it formed eskers, ice-walled channels, kettles and moraines, all of which are abundant throughout the north part of the area. The Cree Lake Moraine, which crosses the centre of the area from east to northwest, represents the major ice frontal position.

Outwash plains and meltwater channels indicate that glacial waters flowed southward to Lake Agassiz and later northward to Lake Athabasca. Raised beaches, as well as the extent and transgressive onlap sequence of lake sediments, document the invasion and various stages in the retreat of Lake Agassiz. Similar features to the west indicate the contemporaneous occurrence of Glacial Meadow Lake which drained to the Clearwater River. Strandlines cut into drumlins and hills around Cree Lake signify that Glacial Cree Lake occupied this isostatically depressed basin. Rebound caused lake waters to spill south to the Mudjatik River channel and later north to the McFarlane-Snare channel and several other drainage ways.

Glacial Lake Athabasca invaded the area around Lake Athabasca as the ice retreated from the Cree Lake Moraine. Strandlines indicate that Glacial Lake Athabasca, which extended to the east as far as Black Lake, had a consistent maximum level of about 305 m. This suggests that isostatic rebound occurred at about the same rate as the ice retreated from the basin. Glacial Wollaston Lake, which occupied the isostatically depressed basin around Wollaston Lake, drained south to Reindeer Lake via the Swan Spillway. When the Fond du Lac River opened the lake drained north into Glacial Lake Athabasca. Scattered raised beaches and some lake sediments indicate that many smaller glacial lakes occurred in the area.

Sand dunes, sand-blasted boulders and loess are remnants of strong eolian activity which occurred shortly after ice retreat. Permafrost persists in peat landforms which are developed in low-lying areas. Lake ramparts and beaches are found along the shores of many of the modern lakes. The various soil profiles are developed primarily in response to the nature of the surficial parent material.

Schreiner, B.T., Alley, D.W. and McNamara, S.J. (1984): Quaternary geology of the Precambrian Shield, Saskatchewan; Saskatchewan Energy and Mines, Open File Reports 84-2 to -21 (series of 1:250,000 scale maps with marginal notes).

These 1:250 000 scale monochrome maps, each sold separately, provide compilations of the Quaternary geology throughout the entire Precambrian Shield area of Saskatchewan. They are the result of an extensive program of airphoto interpretation and field investigations carried out under contract by the Saskatchewan Research Council for the Saskatchewan Geological Survey during the period 1974-80. Funds were provided by the federal Departments of Energy, Mines and Resources (25 percent) and Regional Economic Expansion (25 percent) and by the Province of Saskatchewan (50 percent).

The field studies included traverses, detailed site examinations, shoreline and roadside investigations, augerhole sampling and detailed examination of representative soils. The map units shown are generally complexes of materials, morphologies and drift thicknesses. Maps include marginal notes, augerhole logs, soil profiles and textural triangles. Additional information will be available in Report 221, consisting of text, diagrams, photographs and a 1:1 000 000 scale full colour map, which is scheduled to be published later in 1984.

The following geological bibliographies have been prepared in conjunction with the 1:250,000 scale compilation bedrock geology series and will be updated at regular intervals:

Thomas, M.W. and Slimmon, W.L. (1984): Reindeer Lake North (NTS area 64E), geological bibliography; Saskatchewan Energy and Mines, Data File 1, 9p.

Thomas, M.W. and Slimmon, W.L. (1984): Wollaston Lake (NTS area 64L), geological bibliography; Saskatchewan Energy and Mines, Data File 2, 15p.

Thomas, M.W. and Slimmon, W.L. (1984): Foster Lake (NTS area 74A), geological bibliography; Saskatchewan Energy and Mines, Data File 3, 11p.

Thomas, M.W. and Slimmon, W.L. (1984): Geikie River (NTS area 74H), geological bibliography; Saskatchewan Energy and Mines, Data File 4, 10p.

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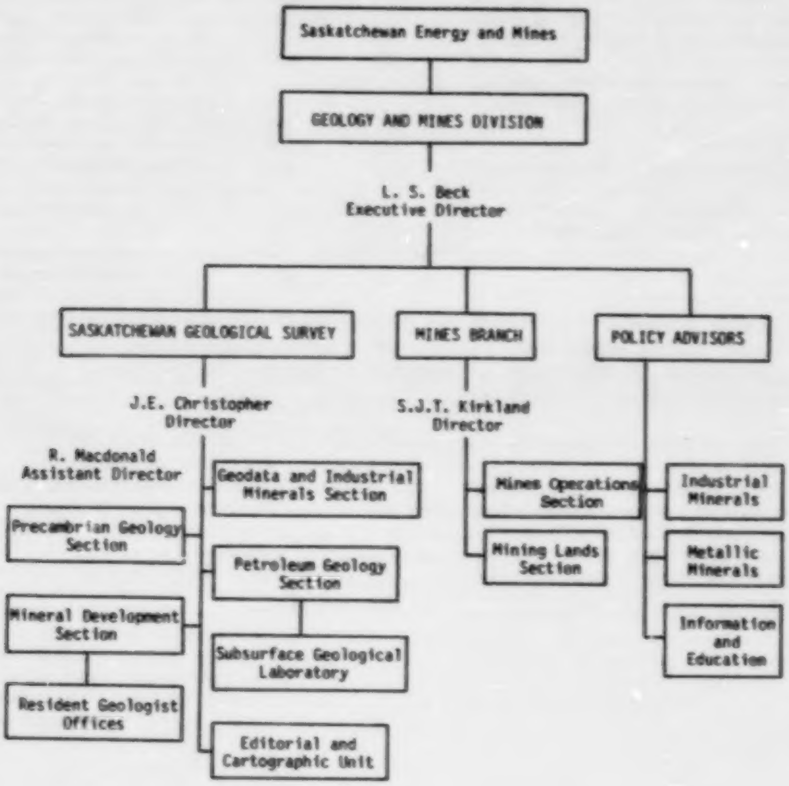
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